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Declaration of the Record of Decision,
Decision Summary, and
Responsiveness Summary

for

Final Remedial Action
Naval Submarine Base Bangor Site F
(Operable Unit 2)
Silverdale, Washington

September 1, 1994

DECLARATION OF THE RECORD OF DECISION

SITE NAME AND LOCATION

Naval Submarine Base Bangor Site F (Operable Unit 2)
Silverdale, Washington

STATEMENT OF BASIS AND PURPOSE

This decision document presents the selected remedial action for Site F (Operable Unit 2) at the Naval Submarine Base (SUBASE), Bangor in Silverdale, Washington, chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), and, to the extent practicable, the National Oil and Hazardous Substances Pollution Control Contingency Plan (NCP). This decision is based on the administrative record for the site.

The remedy was selected by the U.S. Navy as lead agency, and the U.S. Environmental Protection Agency (EPA). The State of Washington Department of Ecology (Ecology) concurs with the selected remedy.

ASSESSMENT OF THE SITE

Actual or threatened releases of hazardous substances from the site, if not addressed by implementing the response action selected in this Record of Decision (ROD), may present an imminent and substantial endangerment to public health, welfare, or the environment.

DESCRIPTION OF THE SELECTED REMEDY

The selected remedy is the only response action planned for Site F (Operable Unit 2). This action addresses contaminated soil and contaminated groundwater. The selected remedy will consist of the following actions:

Soil Remediation

- Excavate soils to a depth of 15 feet which exceed State Model Toxics Control Act (MTCA; Chapter 173-340 WAC) residential contact cleanup levels for ordnance (33 mg/kg TNT; 1.5 mg/kg DNT; and 9.1 mg/kg RDX). The volume of soil to be excavated is estimated to be approximately 1,000 cubic yards;

- Treat the excavated soils by adding organic amendment under controlled conditions to facilitate and enhance biological degradation of ordnance compounds in the soils;

- Monitor the effectiveness of the soil treatment process throughout implementation to ensure its effective operation. Allowances will be made for operational adjustments to optimize reductions in ordnance concentrations in the soil. Soil treatment will reduce ordnance concentrations in the amended soil to the extent possible and, at a minimum, to below MTCA soil cleanup levels for direct contact exposure;

- Upon completion of the biological soil treatment, use the treated soil/amendment mixture to fill and regrade the Site F excavation and overflow ditch;

- Install an infiltration barrier over all soils with concentrations above soil cleanup levels for protection of groundwater; and

- Monitor the condition of the infiltration barrier as needed to ensure its structural integrity.

Groundwater Remediation

- Modify the existing Site F Interim Remedial Action (IRA) groundwater extraction, treatment, and reintroduction system by adding additional extraction wells to enhance, to the maximum extent practicable, the removal of constituents from the Shallow Aquifer at Site F;

- Treat extracted groundwater using granular activated carbon (GAC) for removal of ordnance, and ion exchange as necessary for nitrate removal, to meet MTCA groundwater cleanup levels prior to its reintroduction to the Shallow Aquifer;

- Permanent destruction of the ordnance compounds will be achieved during thermal regeneration of the granular activated carbon at a permitted off-site facility;

- Return the treated water to the SUBASE, Bangor, Shallow Aquifer by means of reintroduction wells;

- Monitor the effectiveness of the groundwater remediation program and make appropriate operational adjustments to optimize, to the maximum extent practical, the removal of constituents from the Shallow Aquifer at Site F; and

- Initiate a formal review (by the Navy, EPA, and Ecology, as defined in Section 19 of the Federal Facilities Agreement) of the groundwater remediation system operation after one of the following performance evaluation criteria, as defined in this ROD, is met:

  (1) Groundwater cleanup levels are achieved for all constituents of concern in the Shallow Aquifer at Site F; or

  (2) No statistically significant change in constituent concentrations is observed, in monitoring wells at Site F which exceed groundwater cleanup levels, after reasonable system enhancements and modifications have been implemented; or

  (3) The rates of constituent concentration reductions in the Shallow Aquifer at Site F indicate that the cost of continued system operation is substantial and disproportionate relative to the incremental degree of environmental protection.

Based on this review, the Navy and EPA, in consultation with Ecology, will determine whether system shutdown, continued system operation, or other remedial response is warranted.

- If the Navy and EPA, in consultation with Ecology, determine that continued groundwater remediation system operation is technically infeasible or impracticable, institutional controls and water quality monitoring within the Shallow Aquifer will be implemented as required by EPA and Ecology to protect human health and the environment until cleanup levels are achieved.

STATUTORY DETERMINATIONS

The selected remedy is protective of human health and the environment, complies with federal and state requirements that are legally applicable or relevant and appropriate to the remedial action, and is cost-effective. This remedy utilizes permanent solutions and alternative treatment or resource recovery technologies to the extent practicable and satisfies the statutory preference for remedies that employ treatment that reduces toxicity, mobility, or volume as a principal element. Because this remedy may result in hazardous substances remaining on site above health-based levels a review will be conducted within a 5-year period, at a minimum, or as required based on the performance evaluation criteria contained herein, to ensure that the remedy continues to provide adequate protection of human health and the environment.

E Lockwood 9/21/94

Captain Ernest Lockwood — Date
SUBASE, Bangor Commanding Officer
United States Navy

Signature Sheet for the foregoing SUBASE, Bangor, Site F, Remedial Action, Record of Decision between the United States Navy and the United States Environmental Protection Agency, with concurrence by the Washington State Department of Ecology.

Jane S. Marre 9-28-94

for Chuck Clarke Date
Regional Administrator, Region 10
United States Environmental Protection Agency

Signature Sheet for the foregoing SUBASE, Bangor, Site F, Remedial Action, Record of Decision between the United States Navy and the United States Environmental Protection Agency, with concurrence by the Washington State Department of Ecology.

Carol Kraege 9/27/94

Carol Kraege, Acting Program Manager — Date
Toxics Clean-Up Program
Washington State Department of Ecology

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ACRONYMS AND ABBREVIATIONS

AKARM	All Known Available and Reasonable Methods
ARARs	Applicable or Relevant and Appropriate Requirements
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
DNB	1,3-Dinitrobenzene
DNT	2,4- and 2,6-Dinitrotoluene
2,4-DNT	2,4-Dinitrotoluene
2,6-DNT	2,6-Dinitrotoluene
Ecology	Washington State Department of Ecology
EPA	Environmental Protection Agency
FFA	Federal Facility Agreement
GAC	Granular Activated Carbon
HDPE	High Density Polyethylene
HEAST	Health Effects Assessment Summary Tables
HPLC	High Performance Liquid Chromatography
IAS	Initial Assessment Study
IRA	Interim Remedial Action
IRIS	Integrated Risk Information System
MCL	Maximum Contaminant Level
mg/kg	Milligram of chemical per kilogram of soil (dry weight)
mg/L	Milligram of chemical per liter of water
μg/L	Microgram of chemical per liter of water
MSL	Mean Sea Level
MTCA	Model Toxics Control Act (Chapter 173-340 WAC)
NA	Not Applicable
NACIP	Naval Assessment and Control of Installation Pollutants
NB	Nitrobenzene
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NPL	National Priorities List
O&M	Operations and Maintenance
ppb	Parts per Billion (equivalent to μg/L)
ppm	Parts per Million (equivalent to mg/kg or mg/L)
PQL	Practical Quantitation Limit
PVC	Polyvinyl Chloride
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine (Royal Demolition Explosive)
RI/FS	Remedial Investigation and Feasibility Study
ROD	Record of Decision
RME	Reasonable Maximum Exposure

SARA	Superfund Amendments and Reauthorization Act of 1986
SUBASE	Naval Submarine Base
SWFPAC	Strategic Weapons Facility Pacific
TBC	To Be Considered
TCLP	Toxicity Characteristic Leaching Procedure
TNB	1,3,5-Trinitrobenzene
TNT	2,4,6-Trinitrotoluene
USGS	United States Geological Survey
UV/Ox	Ultraviolet Oxidation
WAC	Washington Administrative Code

RECORD OF DECISION
FINAL REMEDIAL ACTION
NAVAL SUBMARINE BASE, BANGOR, SITE F
DECISION SUMMARY

1.0 INTRODUCTION

Under the Defense Environmental Restoration Program, it is the U.S. Navy's policy to address contamination at Navy installations in a manner consistent with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). At the U.S. Naval Submarine Base (SUBASE), Bangor, Site F (Operable Unit 2), remedial action will be implemented to minimize potential health risks associated with soil and groundwater contamination. The remedial action will comply with federal and state applicable or relevant and appropriate requirements (ARARs).

2.0 SITE NAME, LOCATION, AND DESCRIPTION

U.S. Naval Submarine Base (SUBASE), Bangor is located in Kitsap County, on Hood Canal approximately 10 miles north of Bremerton, Washington. Site F is located in the south-central portion of SUBASE, Bangor, approximately 1.5 miles east of Hood Canal (Figure 1). Land surrounding SUBASE, Bangor is generally undeveloped or supports limited residential use within the communities of Vinland (to the north), Olympic View and Old Bangor (to the west), and Silverdale (to the south).

Site F (also known as Operable Unit 2) is a former ordnance wastewater lagoon located immediately west of the former Segregation Facility in the southcentral portion of SUBASE, Bangor. The former wastewater lagoon is located in a clearing surrounded by forested area to the north, west, and south. The site occurs in a generally closed basin, which receives surface water inflow from adjacent drainages, but no surface water drainage leaves the area. The ground surface elevation near the disposal lagoon is approximately 300 to 310 feet mean sea level (MSL) and increases to the west until it reaches a plateau ranging in elevation from 375 to 400 feet MSL. The former wastewater disposal site consisted of an approximately 300-square-foot unlined evaporation lagoon and overflow area located adjacent to the Segregation Facility. Local features include a Naval Heli-pad located approximately 700 feet northwest of Site F and barricaded sidings and rail line approximately 1,500 feet west. The only access road into the site is via the Segregation Facility, and it is secured. Access to Site F is restricted to authorized personnel.

3.0 SITE HISTORY AND ENFORCEMENT ACTIONS

The concern over the environmental impact of ordnance operations at SUBASE, Bangor originated from activities prior to its commissioning as a submarine base. From the early 1940s until 1971, the Bangor Naval complex served as a munitions handling, storage, and processing site. Limited demilitarization (demil) operations continued until about 1978. Site F, which represents a former wastewater lagoon and overflow area, was used between approximately 1960 and 1970 for the disposal of wastewater produced during the demilitarization of ordnance items in the adjacent Segregation Facility building. The Segregation Facility consisted of three primary segregation plants and several other smaller buildings. Figure 2 shows the historical features at the site including the location of the former wastewater lagoon and overflow channel.

Between approximately 1957 and 1978, the segregation facility's primary functions included the demil of Mk 6 and Mk 25 rocket warheads; Mk 6, Mk 8, and Mk 9 mines and depth charges; and 5-inch projectiles. These ordnance items contained primarily trinitrotoluene (TNT), Composition A, Composition B, and Amatol. Residues of TNT, hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), and picric acid were identified within the building prior to its decontamination in 1980-81. Demiling activities reached a peak during 1966 to 1970.

The procedures used for the demiling of ordnance items included preliminary cutting or boring of large items using a mechanical tool, followed by steam cleaning; other items were demiled entirely through a steam melt-out process. During the steam-out process, steam was directed into the ordnance, and the resulting condensate and solid explosive were collected within a holding tank. Discharge from the holding tank was then directed into skimming and settling chambers, which removed much of the solid materials from the wastewater before final discharge.

Prior to 1972, the final wastewater solution was discharged through a drain line directly into the former wastewater lagoon. Beginning in 1972-73, wastewater was collected into 55-gallon barrels and delivered to the SUBASE, Bangor liquid-waste incinerator.

The quantity of ordnance demiled within the Segregation Facility is not well-documented. Reportedly, ordnance recovered within the Demil Facility was flaked, boxed, and sent to magazines for future disposition.

Some of these materials were apparently sold back to manufacturers. The quantity of this "recycled" ordnance is not well-documented. Ordnance not recycled was taken either to an ordnance burning area (Site A) located to the north on SUBASE, Bangor or off base for thermal destruction.

As stated above, during the period from 1960 to 1971, wastewater from the Demil Facility was directed to an unlined infiltration and evaporation lagoon and overflow area. Periodically, the lagoon was allowed to dry out by evaporation and/or drain to the overflow ditch south of the lagoon. Waste materials present in surficial sediments of the lagoon were reportedly "burned-off" in place with waste oil during the 1960s, or transported to Site A (Operable Unit 1) for burning and disposal.

In February 1972, 500 cubic feet of soils were excavated from the top several feet of the former lagoon area and delivered to Site A for burning. To further reduce potential migration of contaminants from Site F soil into the Shallow Aquifer, the former lagoon area was backfilled and covered with asphalt in 1980.

Also in 1980, demil operations at the Bangor Segregation Facility were transferred to the Indian Island Annex. The buildings were subsequently decontaminated and converted to storage.

A considerable number of on-site investigations of the distribution and transport of waste constituents at Site F have occurred since 1971. In 1978, the Navy Assessment and Control of Installation Pollutants (NACIP) program was initiated to evaluate waste disposal sites at SUBASE, Bangor, including Site F. Work at Site F continued in 1981 as part of an Initial Assessment Study (IAS) and in 1986 as part of a Characterization Study, both under the Navy Assessment and Control of Installation Pollutants (NACIP) program. In the latter year, Congress enacted the Superfund Amendments and Reauthorization Act (SARA) which required federal facilities to comply with the EPA's procedures at inactive waste sites. As a result, the Navy suspended further NACIP program activities and phased into the EPA Remedial Investigation/Feasibility Study (RI/FS) program.

On July 14, 1989, the EPA proposed SUBASE, Bangor, including Site F, for listing on the National Priorities List (NPL). On August 30, 1990, SUBASE, Bangor was officially listed on the NPL. The RI/FS investigation at Site F was completed in November 1993. Prior to completion of the RI/FS, a Record of Decision (ROD) for an interim remedial action (IRA) was signed in August 1991 to limit further migration of ordnance-contaminated groundwater from Site F. This ROD was amended to provide for the use of granular activated carbon (GAC) for groundwater treatment, and the change was documented in an Explanation of Significant Differences dated May 17, 1994. The IRA groundwater containment system, currently under construction, is designed to hydraulically limit the further migration of groundwater contaminants in the Shallow Aquifer by groundwater extraction. The extracted groundwater will be treated by GAC for ordnance and, as required, will include treatment for nitrate to achieve all groundwater cleanup levels. The treated water will be returned to the Shallow Aquifer through reintroduction wells.

4.0 HIGHLIGHTS OF COMMUNITY PARTICIPATION

The Community Relations Plan for Site F is presented in the RI/FS Management Plan for the site, available for review in the information repositories. Community relations activities have established communication between the Navy and citizens living near SUBASE. The actions taken to satisfy the requirements of the federal law have also provided a forum for citizen involvement and input to the remedial action decision.

The community relations activities at the site included the following:

- Technical Review Committee (TRC) meetings with representatives from surrounding communities;

- Issuance of three fact sheets for the Site F RI/FS, which provided updates on the work being performed and major findings;

- Issuance of a fact sheet for the Site F Interim Remedial Action (IRA), explaining the work being performed; and

- Coordination with citizens groups formed in response to site investigations of concern to the community.

The specific requirements for public participation pursuant to CERCLA Sections 113(k)(2)(b) and 117(a) include releasing the Proposed Plan to the public. This was done in January 1994. The Proposed Plan was placed in the administrative record and information repositories.

The information repositories are located at Kitsap regional libraries:

Central Branch
1301 Sylvan Way
Bremerton, Washington
(206) 377-7601

Bangor Branch (SUBASE access required)
Naval Submarine Base, Bangor
Silverdale, Washington 98315-5000
(206) 779-9724

The Administrative Record is on file at:

Engineering Field Activity, Northwest
Naval Facilities Engineering Command
Olympic Place II
1040 NE Hostmark Street
Poulsbo, Washington
(206) 396-5984

Notice of the availability of the proposed plan, plus notice of a public meeting on the proposed plan and public comment period was published in the Bremerton Sun (January 23, 1994) and Trident Tides (January 28, 1994). The proposed plan was mailed to all interested people on January 21, 1994. A public comment period was held from January 23 to February 22, 1994. A public meeting was held on February 3, 1994, with presentations given by the Navy, EPA, and Ecology. A total of 51 people attended the public meeting.

Twenty-four comments (total) were received by the Navy concerning the Proposed Plan. Most comments were submitted at the public meeting, and one comment letter was submitted to the Navy outside of the public meeting. The public comments are summarized and responses presented in the Responsiveness Summary (Attachment A) portion of this document.

5.0 SCOPE AND ROLE OF OPERABLE UNITS

Two NPL sites exist at SUBASE, Bangor. The first is Bangor Ordnance Disposal Site A (Operable Unit 1), which was listed on the NPL on July 22, 1987. On August 30, 1990, the remainder of SUBASE, Bangor was listed on the NPL, including an additional six operable units comprising 21 known or suspected hazardous waste sites. Site F, identified as Operable Unit 2, is geographically separate from the other operable units at SUBASE, Bangor. This Record of Decision addresses Operable Unit 2 only.

The selected Remedial Action at Site F will minimize potential future health risks associated with soil and groundwater contamination at the site. This action includes soil treatment to address risks posed by direct contact exposures at the site and use of an infiltration barrier to restrict further releases of contaminants from soil to groundwater. The selected groundwater action includes extracting contaminated groundwater from the Shallow Aquifer at Site F, treating it to meet cleanup levels, and returning it to the Shallow Aquifer through a series of wells. The groundwater remedial action addresses principal and low-level risks posed by potential future water supply use of site groundwaters, as well as future groundwater discharge to surface water at seep locations.

6.0 SUMMARY OF SITE CHARACTERISTICS

This section presents a summary of site conditions including a discussion of the hydrogeologic characteristics and site waste constituents. The principal exposure pathway of concern to human health and the environment is the transport of site contaminants in the groundwater beneath the site. Contaminated soils occur at the surface in the overflow ditch and in the subsurface beneath the existing asphalt pavement covering the former wastewater lagoon.

There are no critical habitat areas (including those of threatened or endangered species), wetlands, floodplains, or historic preservation sites in the area covered or affected by the selected remedial action.

6.1 Site Hydrogeologic Conditions

The three aquifer systems which exist beneath Site F are (from shallowest to deepest) the Shallow Aquifer, the Sea level Aquifer, and Deeper Undifferentiated Aquifer(s). Regional hydrogeologic studies indicate that this sequence is regionally consistent. Groundwater contamination from Site F is limited to the Shallow Aquifer, which is not used for water supply at SUBASE, Bangor. The Sea Level Aquifer and deeper aquifers provide the principal water supply for SUBASE, Bangor and surrounding communities. No ordnance contaminants have been detected in the Sea Level Aquifer or in deeper aquifers. The aquitard underlying the Shallow Aquifer is both continuous across the Site F area and competent enough to impede the downward migration of groundwater through it.

Figure 3 shows the location of monitoring wells located at Site F which were used to assess hydrogeologic conditions beneath the site and provide an effective monitoring network to assess groundwater quality. Additional water supply wells at SUBASE, Bangor were also used to define subsurface conditions beneath the Shallow Aquifer. The hydrogeologic units beneath Site F are illustrated on Figure 5, which is oriented east to west (cross section location line shown on Figure 4).

The three hydrogeologic units that have significance for the Final Remedial Action at Site F are:

- Vashon (Glacial) Till;
- Shallow Aquifer; and
- Vashon Proglacial Aquitard.

Subsurface explorations at Site F and other locations on SUBASE, Bangor indicate that this vertical sequence of units is regionally consistent. Each of the three significant hydrogeologic units is described below.

Vashon Till. The Vashon Till consists of a dense, unsorted gravelly, silty sand. The till forms a low permeability veneer over the site which limits the rate of infiltration to the underlying Shallow Aquifer. The thickness of the till ranges from approximately 15 to 45 feet across the Site F area. In the immediate area of the former wastewater lagoon, the till is approximately 15 to 25 feet thick.

Lenses of silt and sand also occur within the till, but they are laterally and vertically discontinuous. Although the isolated sand lenses become seasonally saturated, they do not constitute a perched aquifer system because of their lack of interconnection.

Shallow Aquifer. The Shallow Aquifer is an unconfined (water table) aquifer occurring within a thick sequence of Vashon Advance Outwash sand, which directly underlies the Vashon Till. Depth to water in the Shallow Aquifer ranges from approximately 50 feet near the former wastewater lagoon to more than 150 feet in topographically higher areas to the west. Locally, the aquifer is extensive, with a saturated thickness ranging from 60 to 100 feet.

The advance outwash deposits comprising the aquifer become finer grained with depth, grading from gravelly, coarse to medium sand downward into very silty, fine sand. The lower very silty portion of the outwash is differentiated from the rest of the outwash because of its unique fine-grained nature. Field observations during drilling and confirmatory grain size analyses suggest that the very silty portion of the outwash sand does not readily transmit water, and therefore effectively forms the bottom of the Shallow Aquifer. The Shallow Aquifer is exceptionally uniform across the area and is relatively permeable, with an average horizontal hydraulic conductivity estimated from pumping test and slug test data on the order of 10^{-2} cm/sec.

The Shallow Aquifer water table slopes gently toward the northwest, with a horizontal gradient of approximately 0.003 (3 foot drop for 1,000 feet horizontally). As shown on Figure 6, the groundwater flow direction curves from a northwestern direction near the former lagoon to a more north-northwesterly direction further downgradient. The average linear groundwater flow rate is approximately 200 feet per year.

Vertical hydraulic gradients also exist within the Shallow Aquifer, which appear to affect constituent migration within the aquifer. Downward gradients occur near the former lagoon area, resulting in a downward migration of waste constituents from the source area.

Available geologic and hydrologic information indicates that the Shallow Aquifer discharges in the direction of flow (north-northwest) to on-base seeps (Figure 5) which feed tributaries flowing to Hood Canal. There are no on-base water supply wells completed in the Shallow Aquifer. Although the available information indicates the Shallow Aquifer is not continuous west of the SUBASE, boundary, shallow hand-dug wells in Old Bangor and Olympic View west of the base boundary may be fed by seep discharge from the Shallow Aquifer. The Shallow Aquifer seep discharge is known to flow across the base boundary into small unnamed streams which flow through Old Bangor and Olympic View toward Hood Canal.

Vashon Proglacial Aquitard. The Vashon Proglacial Aquitard is a thick low permeability unit which separates the Shallow Aquifer from deeper aquifer systems in the area (Figure 5). In the Site F area the aquitard is approximately 60 to 80 feet thick and consists of clayey silt with occasional interbedded silty sand and gravel layers. The laboratory-measured average vertical hydraulic conductivity of the aquitard material is approximately 10^{-7} cm/sec, which is on the order of 100,000 times lower than horizontal hydraulic conductivity of the overlying Shallow Aquifer.

6.2 Site Waste Constituents

6.2.1 Soils

Soil quality data were collected by the USGS in 1974 (99 samples), by SUBASE, Bangor in 1981 (74 samples), and by Hart Crowser in 1990 and 1992 (125 samples). Soil samples were collected from ground surface to the water table (depth of approximately 50 feet in 1990 through 1992). The constituents analyzed in the soil samples prior to the Hart Crowser sampling were largely limited to TNT and RDX. All of the soil samples collected within the disposal area (other than the fill) contained detectable concentrations of TNT and RDX. Conversely, only two soil samples collected outside the lagoon and overflow ditch area exhibited detectable ordnance concentrations. Furthermore, these two detections were from samples collected at the water table, suggesting that the presence of the ordnance was likely due to groundwater transport.

The soil quality data confirm that TNT is the primary ordnance constituent present in soils in the disposal area, accounting for more than 90 percent of the ordnance mass in soil. The other ordnance constituents detected at lower concentrations in the disposal area soils include 1,3,5-trinitrobenzene (TNB), 1,3-dinitrobenzene (DNB), and 2,4- and 2,6- dinitrotoluene (DNT). Table 1 summarizes detected soil concentrations for the chemicals of concern at Site F, which were determined during the RI/FS based on the risk assessment.

The waste constituents disposed of at Site F infiltrated through the unsaturated soils to the underlying water table (refer to Figure 7). Termination of discharge and capping of the disposal area in 1980 was successful in restricting water infiltration below the lagoon and reducing further leaching of contaminants from the soil. Comparison of soil quality data collected by the USGS in 1974 and data collected during the RI/FS in 1990 suggests that minimal downward migration of contaminants occurred following placement of the asphalt cap.

The contaminated soil at Site F is not a regulated waste under the Resource Conservation and Recovery Act (RCRA; also implemented pursuant to Washington's Dangerous Waste Regulations - Chapter 173-303 WAC) based on listing or characteristic. Contamination of the waste lagoon soil at Site F did not involve a discarded chemical product nor a listed process. In addition, Site F soils do not exceed designation criteria as a characteristic waste using calculations based on the Toxicity Characteristic Leaching Procedure (TCLP).

6.2.2 Groundwater

Groundwater quality data have been collected at Site F during prior studies beginning in 1974, during development of the Current Situation Report in 1986/1987, and as part of the RI/FS in 1990 through 1992. Groundwater samples have been collected from over 50 on-site wells completed in the Shallow Aquifer. The database includes groundwater sampling data collected by the USGS, by SUBASE, Bangor, and most recently by Hart Crowser.

The lateral and vertical distributions of site waste constituents within the Shallow Aquifer are reasonably well-characterized. The ordnance waste constituents detected have included TNT, RDX, DNT, TNB, and nitrobenzene. Nitrate and low concentrations of various metals and organic chemicals were also detected. A summary of the chemicals of concern in groundwater at Site F is presented in Table 1.

Based on the Table 1 summary, the ordnance constituents detected at the highest concentrations in the Shallow Aquifer were RDX and TNT. RDX is more mobile than TNT and the other ordnance constituents, and has migrated the furthest downgradient from the Site F disposal area. Based on existing data, the bulk of the TNT in the groundwater occurs within approximately 1,000 feet of the former wastewater lagoon area. Nitrate, like RDX, is highly mobile in the Shallow Aquifer. As a result, RDX and nitrate define the outer extent of groundwater contamination in the Shallow Aquifer at Site F, which extend approximately 3,000 feet northwest of the former wastewater disposal lagoon (Figure 8).

As discussed above, groundwater in the Shallow Aquifer flows at a rate of approximately 200 feet/year toward the north-northwest, and discharges as seeps located within the western base boundary. RDX is the most mobile ordnance compound in groundwater at Site F. Based on the observed distribution of RDX in the Shallow Aquifer, RDX appears to be migrating at rate of approximately 100 feet/year. No ordnance compounds have been detected in the seeps. Based on the estimated rate of RDX migration in the aquifer and the distance to the seeps in the direction of groundwater flow, it should take 30 or more years for RDX to reach the seeps, if no remedial response action is taken.

To evaluate the possibility of existing impacts to water supply wells within downgradient communities from Site F, SUBASE, Bangor (in conjunction with the Kitsap County Health District) conducted an annual monitoring program of selected off-site water supply wells from 1984 to 1987. The sampling sites included twelve (12) off-base domestic supplies east and west of Site F, which obtained water from both the Shallow and Sea Level Aquifers. Eight SUBASE, Bangor water supply wells completed within the Sea Level Aquifer or deeper aquifers have also been monitored. Samples collected during the RI/FS field investigation in 1990 from on-base and off-base water supply wells completed in the Sea Level Aquifer and Deeper Aquifers as part of the RI/FS confirmed no ordnance contamination associated with Site F. Samples collected during the RI/FS included the on-base SWFPAC well (used for reserve water supply), which is located downgradient of Site F and is screened solely in the Sea Level Aquifer (Figure 5). In addition, no ordnance compounds were detected in a 1991 sample collected by the State Department of Health from Old Bangor No. 19, located in the community of Old Bangor northwest of Site F.

The contaminated groundwater at Site F is not a regulated waste under RCRA based on listing or characteristic. The contaminated groundwater did not originate as a discarded chemical product (U- and P-listed; WAC 173-303-081) nor did it come from a listed source (F- and K-listed; WAC 173-303-082). Groundwater would not be considered a federal hazardous waste or a state dangerous waste until it is removed (extracted) from the aquifer. Although exceedence of the TCLP threshold concentration for 2,4-DNT was observed in point samples from wells located adjacent to the former waste water lagoon, ordnance concentrations observed during groundwater extraction were below the 2,4-DNT threshold.

7.0 SUMMARY OF SITE RISKS

All chemicals detected at Site F were screened following EPA's 1989 Risk Assessment Guidance for Superfund to identify those chemicals which in combination contribute 99 percent or more of the cumulative site risk. Selection of such indicator chemicals was based on consideration of the concentrations encountered, environmental mobility, and toxicity. Chemicals eliminated in the screening process included several metals (e.g., arsenic), and some ordnance degradation products (e.g., 2,6-diamino-4-nitrotoluene). The eliminated chemicals were either present at concentrations typical of natural background conditions or were below conservative risk-based criteria. Some of the eliminated chemicals lacked quantitative toxicity information necessary to assess human health or environmental risks.

A quantitative human health risk assessment and ecological evaluation was performed for Site F to assess baseline risks at the site under a no-future-action scenario. Only those exposure pathways likely to be important to the overall human health risk assessment were retained for quantitative evaluation, as summarized in Table 2. Reasonable maximum human exposures were estimated for the following pathways:

- Direct skin contact with soil;
- Incidental ingestion of soil, inhalation of air;
- Drinking water consumption of groundwater;
- Direct skin contact with groundwater; and
- Consumption of freshwater aquatic life (future conditions in the seep area).

7.1 Human Health Risks

Based on the above evaluation, chemicals at Site F with the potential to pose a risk to human health were identified. The chemicals of concern identified from this evaluation, listed in decreasing order of calculated risk, are as follows:

- 2,4,6-Trinitrotoluene (TNT);
- 2,4- and 2,6-Dinitrotoluene (DNT);
- Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX);
- 1,3,5-Trinitrobenzene;
- 1,3-Dinitrobenzene;
- Nitrate;
- Nitrite; and
- Manganese.

Other chemicals detected at Site F were below the most conservative risk targets (Hazard Quotient less than 1 and lifetime cancer risk less than 1 in 1,000,000).

A cancer risk level of 1 in 10,000 means that one additional person out of ten thousand is at risk of developing cancer due solely to site conditions if the site is not cleaned up. A hazard quotient (ratio of the level of exposure to an acceptable level) greater than 1.0 indicates that the exposure level exceeds the protective level for that particular chemical. If the hazard quotients for individual chemicals are less than 1.0 but the sum of all chemicals' hazard quotients for an exposure medium (called the hazard index) is greater than 1.0, then there may also be a concern for potential health effects.

Although the existing access and use of Site F is restricted, potential human health risks were evaluated based on the conservative assumption of unrestricted residential use of the site. The risk assessment was also based on a second conservative assumption that a hypothetical residential dwelling would obtain its water supply from the most contaminated portion of the Shallow Aquifer, located next to the former wastewater lagoon. These conservative exposure assumptions allowed site hazards to be evaluated under a Reasonable Maximum Exposure (RME) scenario, consistent with state and federal hazardous site cleanup regulations. Potential exposure pathways are depicted on Figure 9. Tables 3 through 9 provide exposure assumptions used to calculate intake for all pathways. Tables 10 and 11 provide reference doses and slope factors, respectively, for all chemicals of potential concern which were screened in the risk assessment.

For carcinogens, the baseline risk is presented as the possible (upper-bound) risk of contracting some form of cancer given lifetime (30-year) exposure to a chemical. Federal guidelines for acceptable upper-bound cancer risk range from a chance of 10^{-4} (1 in 10,000) to 10^{-6} (1 in 1,000,000) of developing cancer due to exposure to a carcinogen. The comparable cancer risk range recognized by the Washington State Model Toxics Control Act (Chapter 173-340 WAC) is 10^{-5} to 10^{-6}.

Non-carcinogenic risk is evaluated by dividing the daily dose resulting from site exposure by the EPA estimate of acceptable intake (or reference dose) for chronic exposure. If the ratio between these values (termed the Hazard Quotient) is less than 1, then non-carcinogenic risks are not indicated. Conversely, Hazard Quotient values greater than 1 indicate a potential risk to human health.

The calculated Hazard Index and lifetime cancer risk associated with individual chemicals and pathways at Site F are presented in Tables 12 and 13, respectively. A total Hazard Index of 840 and total cumulative RME lifetime cancer risk of 1×10^{-2} were calculated based on a summation of all chemicals and potential pathways at Site F.

Chemicals with a cumulative pathway RME Hazard Index exceeding 1 are (in descending order): TNT (620); TNB (180); DNB (18); RDX (9); DNT (8); nitrate (2); nitrite (2); and manganese (2). Chemicals with a cumulative pathway RME lifetime cancer risk exceeding 10^{-6} are (in descending order): DNT (5×10^{-3}); TNT (4×10^{-3}); and RDX (1×10^{-3}). All other chemicals were below general risk targets (Hazard Index less than 1 and lifetime cancer risk below 10^{-6}).

The pathway-specific RME Hazard Index was highest for combined groundwater exposures (740; drinking water ingestion and water contact), intermediate for combined soil exposures (98; soil contact and incidental ingestion), and lowest for potential future fish consumption (0.7; seep source) and dust inhalation (less than 0.1). A similar relative ranking occurred with RME lifetime cancer risks, with groundwater pathways at 9×10^{-3}, soil pathways at 6×10^{-4}, fish consumption at 1×10^{-5}, and dust inhalation at 5×10^{-7}.

Table 14 provides a summary of the assumptions and uncertainties in the risk assessment. As indicated in this table, most of the assumptions inherent in the risk assessment tend to overestimate site risk, thus providing a conservative evaluation of potential risks associated with Site F.

7.2 Ecological Risk Evaluation

An ecological risk assessment was performed to determine whether the chemicals associated with Site F have the potential to affect local animal populations and ecological communities, particularly valuable ecological resources (e.g., endangered species or wetlands). The assessment addressed both aquatic and terrestrial exposures.

There are no critical habitats or endangered species or habitats of endangered species affected by site contamination. However, future impacts to sensitive aquatic species may possibly occur in the surface water seep area when groundwater chemicals begin arriving in this area. The predicted upper-bound concentration (RME) of TNT in the seep discharge is 76 μg/L (predicted arrival time of approximately 30 years), which exceeds an estimated criterion to protect aquatic life (40 μg/L). The RME condition estimate is based on a hypothetical combination of "worst-case" assumptions to define the physical and chemical transport parameters which affect constituent transport in groundwater (i.e., predict maximum concentrations in the minimum time period). In addition, the predicted RME concentration of TNT does not consider potential exposure to natural sunlight (photolysis). Photolysis has been shown to rapidly degrade TNT in natural waters. Consequently, actual concentrations are likely to be lower than the RME case. The predicted upper-bound concentrations of all other chemicals were either within the range observed in upgradient monitoring wells (background groundwater quality), or below available aquatic life criteria.

Similarly, calculated risk to terrestrial wildlife were also generally below risk criteria. Soil cleanup actions which address human health will also be protective of terrestrial wildlife.

7.3 Need for Remedial Action

The results of the baseline risk assessment indicate that the cumulative cancer risk calculated for Site F exceeds the EPA upper-bound guideline of 10^{-4} (1 in 10,000) assuming most-conservative conditions. Furthermore, potential non-cancer risks exceed human health criteria. The potential for future ecological impacts to sensitive aquatic species were predicted at the seep discharge area if the groundwater contamination arrives there unabated.

Based on these risk assessment results, soil and groundwater contamination at Site F exceeds established health-based thresholds. Consistent with the National Contingency Plan and EPA policy, remedial action is warranted to address these potential risks to human health and the environment.

8.0 CLEANUP STANDARDS

Cleanup objectives (remedial action objectives [RAOs]) for Site F were developed for the affected media and individual chemicals of concern, based on a review of regulatory standards and criteria, and results of the human health and ecological risk assessments. Two primary cleanup action objectives were identified based on site conditions and the principal site risks, specifically: (1) eliminate the risk associated with potential direct contact with contaminated soils at Site F; and (2) cleanup groundwater contamination in the Shallow Aquifer at Site F to achieve the most cost-effective reduction in overall site risk. In addition, chemical-specific RAOs specify the constituents and media of concern, potential exposure pathways, and preliminary remediation goals.

A range of RAOs were developed for soil, groundwater, and surface water, including cleanup goals based on CERCLA threshold risk targets defined relative to a cumulative upper-bound Hazard Index of 1 and a lifetime upper-bound cancer risk of 1 in 10,000. Applicable or relevant and appropriate requirements (ARARs), including drinking water Maximum Contaminant Levels (MCLs), surface water quality standards, and State of Washington Model Toxics Control Act (MTCA) Cleanup Standards were also considered in the development of RAOs. The MTCA Method B cleanup standards provide ARARs for most of the chemicals and pathways of concern at Site F. The media-specific RAOs are listed in Table 15 and are discussed below.

8.1 Soil

The primary chemicals of concern in soil are TNT, RDX, and DNT. Different RAOs for soil were developed to assess two potential exposure pathways: direct soil contact (residential site use scenario) and protection of groundwater use. The soil RAOs based on direct residential soil contact, which apply to a maximum depth of 15 feet (per MTCA), are: TNT (33 mg/kg); RDX (9.1 mg/kg); DNT (1.5 mg/kg); TNB (1.1 mg/kg); and DNB (2.1 mg/kg). The soil RAOs based on protection of groundwater (per MTCA) were determined based on site-specific soil:water partition coefficients and conservative assumptions of site conditions. These groundwater protection RAOs are considerably more stringent: TNT (0.3 mg/kg); RDX (1 mg/kg, based on the current Practical Quantitation Limit [PQL] for Method 8330 HPLC analysis); and DNT (0.5 mg/kg, also based on the PQL). Calculations of the site-specific soil RAOs based on groundwater protection (and corresponding PQLs) are provided in a technical memorandum included in the Administrative Record (technical memorandum included as Attachment A to Responses to EPA Comments on Draft Proposed Plan for Site F, dated December 22, 1993).

An estimated 140,000 cubic yards of soil in the former wastewater lagoon and overflow ditch area exceed the most restrictive soil RAOs (i.e., those based on groundwater protection). By comparison, only about 1,000 cubic yards of soil in these areas exceed direct residential soil contact RAOs.

8.2 Groundwater

Based on the risk assessment, TNT, TNB, DNB, RDX, and DNT are the primary chemicals of concern in the Shallow Aquifer. Nitrate is also a chemical of concern in the Shallow Aquifer; however, it poses far less risk than the ordnance constituents, accounting for less than 1 percent of the non-cancer risk. As discussed above, the extent of RDX and nitrate within the Shallow Aquifer defines the outer boundary of groundwater contamination from all constituents identified at the Site F. The groundwater RAOs are: RDX (0.8 μg/L); TNT (2.9 μg/L); DNT (0.13 μg/L); TNB (0.8 μg/L); DNB (1.6 μg/L); nitrate (10,000 μg/L); nitrite (490 μg/L); and manganese (50 μg/L).

8.3 Surface Water

No impacts to surface water have occurred at the site. Based on protection of human health and the environment, the surface water RAOs for protection of aquatic life are: RDX (260 μg/L); TNT (40 μg/L); DNT (300 μg/L); TNB (80 μg/L); DNB (100 μg/L); nitrate (10,000 μg/L); and manganese (1,500 μg/L). There is no aquatic life surface water RAO for nitrite. Although surface water originating at the seeps is not a current drinking water source, surface water RAOs for drinking water exposure are: RDX (0.8 μg/L); TNT (2.9 μg/L); DNT (0.13 μg/L); TNB (0.8 μg/L); DNB (1.6 μg/L); nitrate (10,000 μg/L); nitrite (490 μg/L); and manganese (50 μg/L).

9.0 DESCRIPTION AND COMPARISON OF ALTERNATIVES

9.1 Soil Remediation Alternatives

A wide range of potential soil remediation alternatives were initially identified for screening in the Feasibility Study (FS) and, of these, seven were selected for detailed analysis in the FS. During development of the Proposed Plan for Final Cleanup of Site F, the soil remediation alternatives were refined, including combination and addition of technologies. The five soil alternatives carried forward in the Proposed Plan are:

(1) No Action;

(2) Limited Action (access restrictions to the site);

(3) Capping of Soils Exceeding Direct Contact and Groundwater Protection Soil Cleanup Levels;

(4) Excavate Contaminated Soils to a Depth of 15 Feet with Concentrations above MTCA Method B Residential Contact Cleanup Levels (1,000 cubic yards), On-Site Biological Soil Treatment, and Placement of an Infiltration Barrier over Remaining Soils Posing a Risk to Groundwater; and

(5) Removal of All Soils Exceeding Most Restrictive Soil RAOs (140,000 cubic yards) and On-Site Incineration.

Discussions of the five soil alternatives are presented below.

No Action

The No Action alternative provides a baseline to compare the other alternatives against to evaluate their effectiveness. The No Action response would entail leaving the site as it currently exists.

Limited Action

Under the Limited Action alternative, existing site controls would be expanded to permanently restrict access to contaminated soils at the site (e.g., fences, etc.). In addition, the Navy would put into effect a permanent order preventing future use of the site.

Soil Capping

The Soil Capping alternative would involve installation of a surface cap over all the contaminated soils at Site F (areal extent estimated at roughly 2 acres). The cap would consist of a synthetic membrane such as PVC or HDPE, which would be sloped for drainage and covered with soil and vegetation for protection. Additional components such as geotextiles and/or sand might also be employed for cushioning and drainage.

In addition to controlling surface water infiltration, the surface cap would provide isolation of the contaminated soil from the atmosphere and from direct contact with humans and animals. The cap would be maintained and repaired as necessary. Because the soil cap would be used to prevent direct contact with contaminated soils, access restrictions would be required to reduce the risk of damaging the cap.

Excavation and On-Site Biological Treatment of "Direct Contact" Soils and Placement of Infiltration Barrier

This alternative involves excavation of all soils to a depth of 15 feet with concentrations above direct contact cleanup levels (e.g., TNT concentrations above 33 mg/kg). MTCA defines a depth of 15 feet as the reasonable maximum depth of direct contact exposure during hypothetical site development. The approximate 15-foot excavation depth is shown on Figure 7. Following excavation, these soils would be mixed with organic amendment (e.g., potato waste, cow manure, sawdust) and subjected to controlled conditions which would facilitate growth of naturally occurring microorganisms in the mixture. The microorganisms would use the contaminant compounds as a food source, transforming the contaminants into less-toxic compounds.

An estimated 1,000 cubic yards of soil will be excavated in this alternative (based on the RI/FS characterization findings). This soil volume would include soils with lower concentrations (below direct contact cleanup levels) which will need to be excavated to reach higher concentration soils below. All excavated soils will be treated together. Verification sampling will be conducted to a depth of 15 feet after excavation. Any remaining soils with concentrations above direct contact cleanup levels, will also be excavated.

Biological treatment would remove chemicals of concern and their degradation products to residual concentrations that are below direct contact RAOs. Recent results of treatability studies performed on a sample of Site F soil indicate that biological treatment is an effective treatment technology for these soils. Because biological treatment has been selected as the preferred alternative for treatment of contaminated soils at Site D (Operable Unit 6), the soils from the two SUBASE, Bangor sites may be treated together.

Excavated glacial till soils present at Site F may require pretreatment by sieving and screening to remove rocks and to break apart the soil. The pre-treated soil would then be mixed with organic amendment, and layered with gravel in biological treatment piles. Soil pile moisture, temperature, oxygen, and nutrient content would be monitored and adjusted as required. Tilling of the soil would be required to supply oxygen and maintain optimum temperature. The biological treatment piles would be sheltered from the rain and provided with adequate ventilation. Run-on would be controlled to eliminate leachate generation and runoff.

Because the biologically treated soils would likely not be in compliance with soil cleanup levels protective of groundwater, the treated soils would be placed back in the excavation prior to installation of the infiltration barrier over those areas. The increased volume of soil which results from biological treatment may be used to fill the overflow ditch to grade prior to placement of the infiltration barrier.

Current treatability study results (based on laboratory testing) indicate that biological treatment can successfully reduce soil concentrations to below all direct contact soil cleanup levels. If pilot testing indicates that biological treatment would not be appropriate for treating ordnance compounds in Site F soils, alternative treatment technologies (e.g., incineration), will be evaluated as a contingency.

The infiltration barrier would consist of a low-permeability material (e.g., asphalt, clay, or geomembrane) used to cover residual soils containing ordnance concentrations that may pose a risk to groundwater quality in the Shallow Aquifer (Figure 11). Soils posing a potential risk to groundwater at Site F cover an area of approximately two acres and extend to the Shallow Aquifer water table (roughly 50-foot depth) over much of that area (Figure 7).

As stated in Section 8.1 above, soil cleanup levels for protection of groundwater default to Practical Quantitation Limits (PQLs) for some ordnance compounds. However, because the groundwater protection soil cleanup levels for Site F were estimated using conservative assumptions, and the volume of soil at Site F with concentrations below PQLs is small, soils with ordnance concentrations at or below PQLs should not pose a risk to groundwater. Furthermore, the infiltration barrier will extend beyond the zone of contaminated soils, thus providing an additional factor of safety.

Like the soil cap discussed in the previous alternative, the infiltration barrier would restrict infiltration of rainwater through contaminated soils, and thus limit migration of contaminants from soil to groundwater. However, unlike the soil cap, the infiltration barrier does not have to provide protection against direct contact with contaminated soils at the site since these soils have been permanently treated to concentrations below direct contact action levels. Therefore, this alternative would not require access restrictions once the soil treatment is completed and the infiltration barrier is in place. As part of remedial design, an operations and maintenance (O&M) plan will be developed for the infiltration barrier to ensure its long-term integrity.

Excavation of All Contaminated Soils and On-Site Incineration

This alternative involves excavation of all contaminated soils (relative to soil cleanup levels for groundwater protection; see Figures 7 and 10) and on-site incineration using a mobile incinerator. Incineration involves the volatilization and combustion of organic contaminants at high temperature (1,600 to 2,000 degrees F). Soil is mixed with a fuel source and combusted in an enclosed, oxidizing environment. Contaminants are converted to inert ash and gases. These gases are further treated to ensure that emissions to the atmosphere meet all air quality criteria.

Although the specific incinerator type would be determined during final design, three incinerator designs in common use are rotary kiln, infrared, and fluidized-bed. Of these, only the rotary kiln incinerator has been demonstrated on ordnance-contaminated soils. The technical and administrative implementability of on-site incineration has been demonstrated at other military installations.

Following incineration, the sterile soil would be used to backfill the excavated area to grade.

9.2 Groundwater Remediation Alternatives

The Site F Feasibility Study included the initial screening of a wide range of groundwater remediation alternatives and detailed evaluation of eight of these. Based on the comparative analysis of alternatives in the Feasibility Study, a more refined list of alternatives was developed for evaluation in Site F Proposed Plan.

The three alternatives evaluated for final groundwater remediation at Site F include:

(1) No Action;

(2) Limited Action (institutional controls restricting groundwater use);

(3) Enhanced Groundwater Extraction, Treatment by Granular Activated Carbon (GAC), and Reintroduction to the Shallow Aquifer.

Discussions of the three groundwater alternatives are presented below.

No Action

The No Action alternative assumes that the Site F IRA is not implemented, long-term groundwater and seep monitoring are not conducted, and no other remedial activities are completed. Under this alternative, migration of ordnance contamination in the Shallow Aquifer would continue.

Limited Action

The Limited Action alternative would consist of deed restrictions prohibiting the installation of water supply wells into the contaminated portion of the Shallow Aquifer. A program of periodic groundwater and surface water sampling and analysis would be instituted to monitor ordnance concentrations in the Shallow Aquifer and at the seeps. If necessary in the future, restrictions on use of the surface water streams fed by the seeps (Shallow Aquifer discharge) may also be required.

Enhanced Groundwater Extraction, Treatment by GAC, and Reintroduction to the Shallow Aquifer

Groundwater would be extracted at a rate to optimize removal of contaminants from the Shallow Aquifer, treated on site using the Granular Activated Carbon (GAC) treatment technology, and returned to the Shallow Aquifer through reintroduction wells. Treatment by GAC is a well-established technology that has been demonstrated to treat Site F groundwater to meet all groundwater cleanup standards. Used carbon would be transported to the carbon supplier's facility for thermal regeneration (reactivation). The regeneration process would provide permanent destruction of adsorbed ordnance compounds. No on-site air emissions would occur under this alternative.

In the Feasibility Study, five different groundwater extraction, treatment, and reintroduction alternatives were evaluated. The five alternatives differed in terms of the groundwater extraction rate and the time period of operation. Two groundwater treatment options, GAC and UV/Ox, were included in each of the five alternatives since they were determined to be the most appropriate for application at the site. However, because GAC provides the same treatment efficiency as UV/Ox at a much lower cost, and because GAC has been chosen for use in the Site F IRA, only GAC was carried forward for evaluation of a final groundwater treatment alternative for Site F.

Groundwater Extraction. Groundwater remedial alternatives were evaluated based on results of numerical contaminant transport modeling during design of the Site F Interim Remedial Action (IRA), and as part of the Feasibility Study. The number and locations of new extraction wells (in addition to those extraction wells installed for the Site F IRA), and their respective pumping rates, will be evaluated by conducting additional groundwater modeling during design of the final groundwater remediation system.

Groundwater modeling evaluations were conducted in an effort to predict the effectiveness of groundwater extraction in removing contaminants from the Shallow Aquifer. The general findings of the groundwater modeling results included:

(1) The existing Interim Remedial Action (IRA) groundwater extraction, treatment, and reintroduction system (225 gpm target pumping rate) currently being implemented by the Navy to limit further migration of contamination in the Shallow Aquifer at Site F is not sufficient to achieve the groundwater RAOs (drinking water standards) in a reasonable time period.

(2) A groundwater extraction system pumping rate of 425 gpm or greater (enhanced system) will likely be required to optimize contaminant removal from the Shallow Aquifer.

(3) Based on conservative contaminant transport assumptions, substantial reduction in ordnance contamination concentrations in the Shallow Aquifer by groundwater extraction is feasible, especially during the early period of system operation when dissolved constituent concentrations within the Aquifer will be high. Based on the modeling results, achieving the RAOs for all chemicals of concern is considered feasible. However, it is difficult at this point to predict with certainty how well the groundwater extraction system performance will compare to the model results. The four principal contaminants of concern—RDX, TNT, DNT, and nitrate—vary in terms of their mobility based on soil:water partitioning. Consequently, removal of these chemicals from the Shallow Aquifer is also indicated to vary. Nonetheless, even considering these uncertainties, groundwater extraction is considered the best means of permanently addressing the groundwater contamination at Site F. Actual contaminant removal performance data collected during implementation of the Site F IRA will greatly improve the ability to predict the degree of aquifer restoration achievable by groundwater extraction and treatment.

(4) Results of the groundwater modeling indicate that, at an extraction rate of approximately 425 gpm, the RDX cleanup level would be achieved in approximately 6 to 10 years (and nitrate even more rapidly), whereas TNT and DNT remediation may require an additional 5 to 20 years of groundwater treatment.

(5) Groundwater in the immediate vicinity of the former wastewater lagoon contains the highest concentrations of the least mobile ordnance constituents, TNT and DNT, and therefore will require

the longest time period of groundwater extraction system operation to achieve cleanup levels. It is anticipated that the initial groundwater extraction system will be designed to focus on removal of the more mobile constituents, RDX and nitrate, and thereby greatly reduce the overall zone of groundwater contamination. The groundwater extraction system will likely require enhancements (e.g., distribution of pumping rates) as the zone of contamination is reduced to the less mobile (slower desorption) constituents, TNT and DNT. Such modifications may include increased pumping or pulse pumping in the vicinity of the former lagoon to optimize removal of TNT and DNT. System modifications (e.g., pulse pumping) may also be used as appropriate to enhance removal of RDX and/or nitrate.

Startup and operation of the IRA groundwater extraction system will provide valuable information on actual ordnance constituent removal rates over time which will allow improved prediction of system performance. This information will be useful in optimizing the final design of the groundwater extraction system.

Groundwater Treatment. Extracted groundwater will be treated using GAC, and ion exchange as necessary to remove nitrate, to meet all ARARs (drinking water standards) prior to reintroduction back to the Shallow Aquifer.

Groundwater Reintroduction. Consistent with the Record of Decision for the Site F IRA, treated groundwater will be reintroduced back into the Shallow Aquifer. This disposal option facilitates on-base disposal of the treated groundwater and minimizes concern for depletion of the groundwater resource. This groundwater recharge can potentially be designed to assist in preventing groundwater contamination migration and accelerate contaminant removal. Based on evaluations conducted during design of the Site F IRA, reintroduction will be conducted through a series of reintroduction wells completed in the Shallow Aquifer. Six reintroduction wells have been completed as part of the Site F IRA.

10.0 SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

Each of the soil and groundwater remediation alternatives discussed above were evaluated against the nine criteria specified by the NCP. The No Action Alternative was included as a baseline comparison. The nine criteria include two threshold criteria which must be met for an alternative to be selected, five balancing criteria for comparing and choosing a preferred alternative, and two modifying criteria (State acceptance and community acceptance) which are factored into selection of the final cleanup action. The following is a comparison of the soil and groundwater alternatives based on the NCP evaluation criteria.

10.1 Evaluation of Soil Remediation Alternatives by Criteria

Overall Protection of Human Health and the Environment. Two of the four soil alternatives, Treatment of "Direct Contact" Soils with Placement of Infiltration Barrier, and Treatment of All Contaminated Soils are protective of human health and the environment. Both of these alternatives eliminate risk due to direct contact with contaminated soils using permanent treatment. Both alternatives also limit further migration of contaminants from soils to the Shallow Aquifer, and thus are protective of the Shallow Aquifer.

The Soil Capping alternative limits potential exposure to contaminated soils at Site F, and limits migration of contaminants into the Shallow Aquifer. However, because no permanent treatment is conducted in this alternative, it is considered to be less protective than either of the soil treatment alternatives. Limited Action prevents exposure to contaminated soils through institutional controls, but provides no protection to the Shallow Aquifer from contaminated soils and provides no permanent treatment. No Action is not protective of human health or the environment, and thus will not be considered further in this evaluation.

Compliance with ARARs. Both soil alternatives with a soil treatment component, the Treatment of "Direct Contact" Soils and Placement of Infiltration Barrier, and Treatment of All Contaminated Soils alternatives, also achieve ARARs. The Limited Action alternative does not achieve ARARs since MTCA does not recognize institutional controls as a substitute for technically feasible cleanup actions. The Soil Capping alternative (containment) complies with the MTCA ARARs only if permanent treatment is demonstrated to be impracticable. Since Ecology has determined that soil treatment is practicable, Soil Capping does not by itself achieve all ARARs.

Soils at Site F do not designate as characteristic dangerous or hazardous wastes and are not listed hazardous wastes. Therefore, handling, treatment, and disposal requirements for dangerous and hazardous wastes are not ARARs for soil remediation at Site F.

Long-Term Effectiveness and Permanence. Both soil treatment alternatives, Treatment of "Direct Contact" Soils and Placement of Infiltration Barrier, and Treatment of All Contaminated Soils, permanently eliminate the risk due to direct contact with contaminated soils at Site F.

Both of these alternatives also provide long-term protection of the Shallow Aquifer, but by different means. Treatment of "Direct Contact" Soils includes the placement of an infiltration barrier which will restrict infiltration, and thus limit leaching of contaminants into the Shallow Aquifer from residual contaminated soils. Treatment of All Contaminated Soils removes and permanently treats all soils posing a potential risk to groundwater quality. The Soil Capping alternative would prevent direct contact with contaminated soils and would reduce migration of contaminants from soil to the Shallow Aquifer, but provides no permanent treatment. The Soil Cap could be effective in the long-term with proper maintenance and site access restrictions to ensure its integrity. The long-term effectiveness of the Limited Action alternative in preventing direct contact with contaminated soils is dependent on compliance with the access and land-use restrictions.

Reduction of Toxicity, Mobility, or Volume Through Treatment. The Treatment of "Direct Contact" Soils and Placement of Infiltration Barrier alternative, and Treatment of All Contaminated Soils alternative include a reduction in toxicity and contaminant volume through treatment. In addition, placement of the Infiltration Barrier greatly reduces mobility of contaminants in the unsaturated zone. Treatment of All Contaminated Soils involves removing all soil contaminants, thus providing complete reduction of toxicity, mobility, and volume through treatment. The Soil Capping alternative reduces the mobility of soil contaminants by restricting infiltration of rainwater through contaminated soils, but does not reduce either the toxicity or volume of contaminated soils through treatment. Limited Action provides no reduction in toxicity, mobility, or volume of soil contaminants.

Short-Term Effectiveness. The Limited Action alternative is very effective at reducing risk to human health and the environment in the short term. The Soil Capping alternative would provide protection from contact with contaminated soil within about two to four months. The Treatment of "Direct Contact" Soils and Placement of Infiltration Barrier alternative would require roughly six months from time of treatment startup to achieve protection. Because of the much larger soil volume to be excavated and treated, the Treatment of All Soils alternative would require roughly two years from startup to achieve protection, and is thus less effective in the short term. Access restrictions currently in place at SUBASE, Bangor would afford short-term effectiveness to all the soil alternatives to non-construction worker exposure. Dust control would be implemented during excavation in both of the soil treatment alternatives to limit exposure to workers or off-site persons.

Implementability. Limited Action is the most implementable alternative since fences or other measures could be constructed quickly around the area of soil contamination, and land-use restrictions could be implemented quickly. The Soil Capping alternative is highly implementable since it uses established techniques and materials, including locally available soils.

Treatment of "Direct Contact" Soils and Placement of Infiltration Barrier is considered to be relatively implementable. Biological soil treatment may require relatively large volumes of organic amendment (potato waste, cow manure, sawdust, etc.) be added to the soil, to provide amendment:soil volume ratios as high as 70:30. Placement of the Infiltration Barrier (which may be as simple as asphalt pavement covered with fill) would be highly implementable.

Because of the large quantity of soils associated with the Treatment of All Contaminated Soils alternative (200,000 tons) and the necessity of using deep-pit excavation techniques, this alternative is considered less implementable than the others. Furthermore, there are technical and administrative concerns associated with incinerating this very large quantity of soil.

Cost. The cost of each soil remediation alternative, in order of increasing present worth, is shown below:

Alternative	Capital Cost	Annual O&M Cost	Present Worth Cost (1)
No Action	$0	$0/yr	$0
Limited Action	$74,000	$1,000/yr	$88,000
Soil Capping	$250,000	$5,000/yr	$320,000
Treatment of "Direct Contact" Soils and Placement of Infiltration Barrier	$1,000,000	$0/yr	$1,000,000
Treatment of All Contaminated Soils	$77,000,000	$0/yr	$77,000,000

Notes:

(1) Present worth estimate assumes a 6 percent discount rate and 30 years of O & M. Cost estimates in 1994 dollars.

(2) The Treatment of "Direct Contact" Soils and Placement of Infiltration Barrier alternative would cost $2,500,000 if incineration, rather than biological treatment, was used to treat the 1,000 cubic yards of contaminated soils.

State Acceptance. The State of Washington has reviewed the soil alternatives and approved this document and the proposed alternative.

Public Acceptance. The public has had the opportunity to review and comment on the range of soil alternatives proposed for remedial action at Site F. The overall supportive public comments received during the comment period for the Proposed Plan for Final Remedial Action at Site F and at the public meeting, has been taken as acceptance of the proposed alternative.

10.2 Evaluation of Groundwater Remediation Alternatives by Criteria

Overall Protection of Human Health and the Environment. The No Action alternative would not provide protection of human health and the environment, and thus will not be considered further in this evaluation. The Limited Action alternative would provide protection of human health by restricting consumption of contaminated groundwater in the Shallow Aquifer; however, it may not be protective of potential ecological receptors at the seep if ordnance breakthrough concentrations there exceed chronic or acute water quality criteria in the future. The Enhanced Groundwater Treatment alternative would provide protection of human health and the environment at the seeps and, depending on system performance, may be effective at providing overall protection throughout the Shallow Aquifer. Groundwater treatment by GAC would achieve groundwater RAOs prior to reintroduction into the Shallow Aquifer.

Compliance with ARARs. The No Action alternative and the Limited Action alternative would not achieve ARARs for groundwater and would likely exceed ARARs for surface water in the future at the seeps. The results of the groundwater modeling indicate that the Enhanced Groundwater Treatment alternative would likely achieve ARARs; however, actual system effectiveness may vary from the groundwater model simulation results. If it is impracticable to achieve all ARARs by the Enhanced Groundwater Treatment alternative, institutional controls would be implemented.

Long-Term Effectiveness and Permanence. The long-term effectiveness of institutional controls implemented under the Limited Action alternative could be assured as long as the contaminated portion of the Shallow Aquifer downgradient of Site F remains under the control of SUBASE, Bangor. The Enhanced Groundwater Treatment alternative provides long-term effectiveness by using permanent treatment processes.

Reductions in Toxicity, Mobility, or Volume Through Treatment. The Enhanced Groundwater Treatment alternative provides a permanent reduction in contaminant toxicity, mobility, and volume. The GAC treatment includes permanent destruction of contaminants during off-base regeneration of the used carbon.

Short-Term Effectiveness. The Limited Action alternative would immediately restrict use of contaminated groundwater within the Shallow Aquifer downgradient of Site F. The Enhanced Groundwater Treatment alternative could be constructed relatively quickly by supplementing the current Site F IRA, which will be operational in 1994.

Implementability. The Limited Action alternative would be easily implementable since all contaminated groundwater in the Shallow Aquifer downgradient of Site F is contained well within SUBASE, Bangor property. There are no water supply wells in the Shallow Aquifer on SUBASE, Bangor. Because the Shallow Aquifer is not needed for on-base water supply, SUBASE, Bangor could easily restrict future installations of on-base water supply wells within the zone of groundwater contamination in the Shallow Aquifer downgradient of Site F. The Enhanced Groundwater Treatment alternative is readily implementable by enhancing the current Site F IRA. In addition, this alternative uses a groundwater treatment technology (GAC) with demonstrated performance for the ordnance contaminants present at Site F groundwater.

Cost. The cost of each groundwater remediation alternative, in order of increasing present worth, is shown below:

Alternative	Capital Cost	Annual O&M Cost	Present Worth Cost [1]
No Action	$0	$0/yr	$0
Limited Action	$40,000	$21,000/yr	$330,000[2]
Enhanced Groundwater Extraction, GAC Treatment, and Reintroduction	$2,100,000	$160,000/yr	$3,300,000 to 4,300,000[3]

Notes:
(1) Present worth cost estimates assumes a 6 percent discount rate. Cost estimates are in 1994 dollars.
(2) Cost for Limited Action assumes 30 years of monitoring.
(3) Range in cost for the Enhanced Groundwater Treatment alternative corresponds to an assumed treatment period of 10 to 30 years.

State Acceptance. The State of Washington has reviewed the groundwater alternatives and approved this document and the proposed alternative.

Public Acceptance. The public has had the opportunity to review and comment on the range of groundwater alternatives proposed for remedial action at Site F. The overall supportive public comments received during the comment period for the Proposed Plan for Final Remedial Action at Site F and at the public meeting, has been taken as acceptance of the proposed alternative.

11.0 THE SELECTED REMEDY

The alternative selected for the remedial action at Site F includes Treatment of "Direct Contact" Soils and Placement of an Infiltration Barrier, and Enhanced Groundwater Extraction, Treatment, and Reintroduction. This alternative is preferred because it best achieves the cleanup objectives and fully addresses the risk posed by contamination at Site F. The remedy employs permanent treatment of contaminants, and thereby provides long-term protection of human health and the environment.

The remedial action plan, which will cost an estimated $4.3 to 5.3 million (present worth) includes the following actions:

11.1 Soil Remediation

- Excavate contaminated soils to a depth of 15 feet with concentrations above MTCA Method B residential contact cleanup levels (estimated soil volume of 1,000 cubic yards).

- Conduct verification soil sampling during and/or following the excavation to assure that all soils exceeding the direct contact cleanup levels to a depth of 15 feet have been excavated. Compliance with the cleanup standards shall be evaluated using compliance monitoring procedures which will be described in a compliance sampling and analysis plan (in accordance with Chapter 173-340 WAC).

- Physically mix the excavated soils with organic amendment, and place the soil/amendment mixture into a structure designed specifically to house the biological treatment process. The type of amendment, soil:amendment ratio, and other operating parameters (e.g., temperature and moisture) will be determined during final design. Soils from Site F and from Site D (Operable Unit 6) may be treated together in a single process.

- Treatment will be considered completed when ordnance concentrations in the soil/amendment mixture are below the MTCA Method B direct contact soil cleanup levels for ordnance (Table 15). Compliance with the cleanup standards will be determined using compliance monitoring provisions defined in Chapter 173-340 WAC. If the biological treatment does not achieve soil cleanup levels, alternative soil treatment methods (e.g., incineration) will be evaluated.

- Upon completion of the soil treatment, the treated soil/amendment mixture will be used to fill and regrade the Site F excavation and overflow ditch to provide a generally flat surface over which to place the infiltration barrier.

- Install an infiltration barrier over all soils with concentrations above soil cleanup levels for protection of groundwater (adjusted for current PQLs; Table 15). The infiltration barrier is estimated to cover approximately 2 acres. The type of material used for the barrier will be decided during final design. Depending on the design, the infiltration barrier may be subsequently covered with uncontaminated soil both to allow revegetation and to provide greater protection against physical and chemical (e.g., sunlight) degradation. An operations and maintenance plan will include periodic inspection of the infiltration barrier, as needed, to ensure its long-term integrity.

11.2 Groundwater Remediation

- The Site F IRA groundwater extraction, treatment, and reintroduction system will be enhanced by installation of additional groundwater extraction wells positioned to provide efficient removal of contaminant mass from the Shallow Aquifer. Additional granular activated carbon (GAC) treatment capacity and additional reintroduction wells will also be added to handle the higher system flow rate. Details regarding extraction and reintroduction well locations, depths, and pumping rates, and the enlarged GAC treatment system will be determined during final design. It is anticipated that a system flow rate of 425 gpm or greater will be required in the enhanced treatment system to achieve groundwater cleanup objectives in a reasonable period of time.

- The objective of the groundwater remediation will be to reduce contaminant concentrations to below cleanup levels (as defined in Table 15) in Shallow Aquifer monitoring wells at Site F. The objective of the IRA at Site F, is limited to preventing further contaminant migration (the IRA containment level is different from the cleanup level). However, like the IRA, the extracted groundwater will be treated to meet drinking water standards groundwater cleanup levels prior to its being returned to the Shallow Aquifer.

- The effectiveness of the Shallow Aquifer restoration program at Site F will be monitored and evaluated as a component of operation and maintenance. Water quality data collected as part of the performance monitoring will be used to evaluate effectiveness and progress of groundwater remediation relative to established cleanup levels. Trends in water quality data will also be used to determine whether changes in system operations, including modifications and enhancements, are necessary, to improve performance or whether formal review of continued system operations and potential system shutdown is warranted. A formal review of continued system operation will be initiated, after one of the following performance evaluation criteria is met:

  1) Groundwater cleanup levels are achieved for all chemicals constituents of concern, namely RDX, TNT, DNT, and nitrate at Shallow Aquifer monitoring wells at Site F; or

  2) Groundwater contaminant constituent concentrations are no longer being reduced (no statistical change in contaminant concentration in the Shallow Aquifer attributable to system operation) by the continued operation of the enhanced groundwater extraction system, after appropriate enhancements and modifications have been made; or

  3) Groundwater contaminant concentrations are declining at a rate such that the cost of continued enhanced groundwater extraction system operation, after appropriate enhancements and modifications have been made, is substantial and disproportionate to the beneficial risk reduction which would be achieved.

A formal review will be scheduled within one (1) month of the date of request by the Navy. These performance evaluation criteria will be considered by the Navy, EPA, and Ecology as part of the formal review, in determining whether system shutdown or other remedial measures is warranted. Section 11.6 provides the rationale and basis of the performance evaluation criteria including statistical procedures and practicability considerations, and the specific methodology for evaluating system performance utilizing these criteria.

11.3 Well Decommissioning

Some groundwater monitoring wells previously installed by the Navy and the USGS at Site F are no longer of use since they are either screened above the current water table or are in close proximity to newer wells. Furthermore, because well construction documentation for several of these older wells are lacking, it is uncertain if they were constructed in compliance with current Washington State well construction regulations. All such wells will be decommissioned in accordance with Chapter 173-160 WAC, or as approved by Ecology.

11.4 Groundwater Remedial Action Measures and Goals

The goal of the groundwater remedial action is to restore the Shallow Aquifer waters to support possible future drinking water use. Based on information obtained during the RI, and the analysis of all remedial alternatives, the Navy, EPA, and Ecology believe that the selected remedy will likely be able to achieve this goal. However, the ability to achieve groundwater cleanup levels at all monitoring wells within the Shallow Aquifer at Site F cannot be determined until the enhanced system has been implemented, modified as necessary, and the groundwater extraction system performance monitored over time.

The selected remedy will include groundwater extraction, treatment, and reintroduction, during which time the system's performance will be carefully monitored on a regular basis and adjusted as warranted by the performance data collected during operation. Modifications may include any or all of the following:

- Discontinuing pumping at individual extraction wells where cleanup goals have been attained;

- Alternating pumping rates at extraction wells to eliminate stagnation points;

- Pulse pumping to allow aquifer equilibrium and encourage adsorbed contaminants to partition into groundwater; and

- Installing additional extraction in the Shallow Aquifer to facilitate or accelerate cleanup of groundwater contaminants.

Remedial actions which allow hazardous substances, pollutants, or contaminants to remain on site must be reviewed not less than every five years after initiation, to ensure the remedy continues to be protective of human health and the environment. Performance evaluation criteria, as presented in Section 11.2, will be used to monitoring system performance and to determine whether formal review of continued system operation is warranted. These reviews may result in system shutdown, further modification of the treatment process, consideration of other remedial approaches, or revision of the cleanup levels. Changes to the selected remedy or cleanup levels would require formal notification to the public.

11.5 Effectiveness of Treatment Technology

Biological Treatment of Soils

Biological treatment is the selected treatment technology for ordnance contaminants present in excavated Site F soils with concentrations above direct contact levels (e.g., TNT concentrations above 33 mg/kg). Based on bench-scale treatability study results, biological treatment will reduce ordnance concentrations to below direct contact action levels. If upcoming pilot testing indicates that biological treatment may not be effective for Site F soils, then incineration will be the back-up treatment technology. Incineration has been demonstrated to be effective in treating ordnance compounds in soils at other military installations.

GAC Treatment of Groundwater

Granular Activated Carbon (GAC) is the selected treatment technology for ordnance contaminants present in groundwater at Site F. It is a proven technology which has been used extensively at the commercial scale to remove ordnance compounds from water. Mobile GAC units have been used to treat Site F groundwater generated during the Site F IRA extraction well pumping tests to below cleanup levels. Contaminants adsorbed on the GAC will be permanently destroyed during the thermal regeneration process conducted off site.

In addition to GAC, extracted groundwater will be treated, as necessary, to achieve the cleanup level for nitrate. Exceedence of the nitrate cleanup level may occur during initial system startup. Nitrate concentrations in treated groundwater are predicted to drop below cleanup levels shortly after startup.

11.6 Groundwater Remediation Performance Evaluation Criteria

Based on the results of contaminant transport modeling and preliminary remedial design analyses, groundwater contaminant reduction is anticipated to progress from initial removal of the more mobile and aqueous phase contaminants such as RDX and nitrate, to the less mobile constituents such as TNT and DNT. Groundwater cleanup standards for RDX will likely be achieved in a time period of approximately 5 to 10 years (nitrate likely more rapidly).

As the RDX and nitrate cleanup standards are attained in the Shallow Aquifer at Site F, the extent of contamination is predicted to decrease substantially. Subsequent groundwater extraction and treatment efforts will then focus on the zone of elevated TNT and DNT concentrations in the Shallow Aquifer, largely restricted to within approximately 1,500 feet of the former lagoon. Because of this condition, along with uncertainties in the transport (especially desorption) behavior of TNT and DNT in the Shallow Aquifer, the groundwater extraction system will likely require modifications over time to optimize removal of these constituents. Possible modifications are summarized in Section 11.4.

Practical modifications to the remediation system will be evaluated to assess whether such improvements would further enhance contaminant removal. Modifications to the groundwater remediation system will be made if the evaluation indicates that further contaminant removal is feasible. Continued modifications will not be required if such enhancements are shown to be ineffective at further contaminant reduction or other more practicable solutions are identified. Based on the results of studies and computer modeling analyses performed to date, and assuming successful modifications of the groundwater extraction system over time, TNT and DNT cleanup levels may be achieved within the Shallow Aquifer at Site F within a time period of 10 to 30 years after system startup. If groundwater cleanup levels are not achieved, institutional controls and/or other measures required by EPA and Ecology will be implemented to protect human health and the environment.

Given current uncertainties in the behavior of chemical transport within the Shallow Aquifer, it is difficult to predict how well the actual system performance will match the predicted model results. Consequently, performance evaluation criteria are provided for establishing when formal review of the groundwater remediation system operation by the Navy, EPA, and Ecology, is appropriate. Decision analysis considerations including technical feasibility and practicability (disproportionate cost versus beneficial risk reduction), consistent with the intent of the National Contingency Plan (NCP) and MTCA, are provided as guidance in evaluating whether continued system operation is warranted. The formal review process will be used to determine the need for contingent groundwater remedial actions, which may include hydraulic containment or system shutdown and implementation of institutional controls.

The groundwater remediation system at Site F will be monitored, evaluated, and modified as appropriate to optimize its effectiveness in achieving all groundwater cleanup standards. Water quality data collected as part of performance monitoring will be used to evaluate the effectiveness and progress of groundwater remediation and provide the basis for implementing formal review outside of the normal 5-year period. A formal review to evaluate continued system operation, will be initiated after one of the following performance evaluation criteria is met:

1) **Groundwater cleanup standards are achieved for all chemicals of concern within the Shallow Aquifer at Site F.** Compliance with the cleanup standards in this case shall be evaluated using compliance monitoring procedures defined in Chapter 173-340 WAC and EPA's 1992 "Methods for Evaluating Attainment of Cleanup Standards, Volume 2: Ground Water", or other applicable future guidance. Based on the information currently available to forecast system performance, the Navy, EPA, and Ecology anticipate that the selected remedy will likely be able to achieve this compliance standard.

2) **Constituent concentrations in excess of the groundwater cleanup standards are no longer being reduced (defined as no statistically significant reduction in constituent concentrations in the Shallow Aquifer attributable to system operation).** In making this determination, reasonable system enhancements and modifications must have already been implemented and demonstrated to be ineffective. The technical feasibility of further groundwater cleanup will be evaluated in accordance with EPA's 1993 "Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration" and other applicable guidance. The lowest technically achievable concentration shall represent a "leveled-off" value of contaminant concentration versus time based on established procedures for regression analysis including evaluation of uncertainty based on the regression error (analysis of residual). The specific groundwater compliance monitoring locations and sampling frequency will be specified by a compliance monitoring plan to be developed as part of the final system design (post-ROD).

   If regression analyses of concentration versus time for data collected from the compliance monitoring wells reveal that the slope of the curve is not different from zero at the 95 percent confidence level (based on Students-t test), then a formal review of continued system operation will be initiated. If the system is shutdown following review and concurrence by EPA and Ecology, institutional controls and/or other measures required by EPA and Ecology will be implemented to protect human health and the environment. Long-term water quality monitoring will be required until groundwater cleanup levels are attained in the Shallow Aquifer at Site F.

3) **Constituent concentrations in excess of the groundwater cleanup standards are declining at such a slow rate that the incremental cost of continued groundwater extraction system operation is considered to be substantial and disproportionate to the incremental degree of environmental protection.** This determination will be based on an evaluation of water quality monitoring data, overall system performance including appropriate enhancements, potential risk posed by leaving residual contaminants in-place, and cost of continued operation. Given the uncertainty in actual system performance, the Navy, EPA, and Ecology have established 30 years as a reasonable maximum period of system operation. However, information collected during system operation, after reasonable measures are taken to enhance system performance, may support system shutdown within a shorter timeframe, based on impracticability, within the meaning set forth in the NCP and MTCA.

The general analysis will be based on a comparison of risk reduction (incremental environmental protection) versus incremental cost for continued system operation versus other remedial response measures which may include lower preference alternatives such as institutional controls. This analysis will be consistent with the methodology for comparative analysis of remedial alternatives presented in the Site F Final Remedial Investigation/Feasibility Study (RI/FS), dated November 1993, and as a component for remedy selection in the Proposed Plan for Remedial Action, dated February 1994.

The Navy may request a formal review if continued system operation can be demonstrated to be impracticable. The formal review will be initiated to determine whether system operation should continue or whether other more practicable remedial response actions are warranted. If the system is shutdown following review and concurrence by EPA and Ecology, institutional controls and/or other measures required by EPA and Ecology will be implemented to protect human health and the environment. Long-term water quality monitoring will be required until groundwater cleanup levels are achieved in all monitoring wells in the Shallow Aquifer at Site F.

12.0 STATUTORY DETERMINATIONS

The remedial action for implementation at SUBASE, Bangor, Site F (Operable Unit 2) is consistent with CERCLA and, to the extent practicable, the NCP. The selected remedy is protective of human health and the environment, attains ARARs unless technically impracticable, and is cost effective. The selected remedy also satisfies the statutory preference for treatment which permanently and substantially reduces mobility, toxicity, or volume of contamination as a principal element. Additionally, the selected remedy uses alternate treatment technologies or resource recovery technologies to the extent practicable.

12.1 Protection of Human Health and the Environment

The selected remedial action will protect human health and the environment through permanent treatment of soils to eliminate direct contact risk, installation of an infiltration barrier to prevent further impacts to the Shallow Aquifer from residual contaminated soils, and extraction and treatment of ordnance in groundwater. The treatment standards support the highest beneficial use of these media (i.e., residential land use and water supply), and are protective of human health and the environment. The ordnance contaminants will be permanently removed from the soil by biological degradation to less toxic byproducts, and from groundwater by adsorption to activated carbon with permanent destruction during thermal regeneration. As necessary, groundwater will be further treated for nitrate to ensure that the treated water meets all RAOs prior to its return to the Shallow Aquifer.

12.2 Compliance with Applicable or Relevant and Appropriate Requirements

The selected remedy will comply with all applicable or relevant and appropriate chemical-, action-, and location-specific requirements (ARARs). The ARARs are presented below.

Action-Specific ARARs

- State of Washington Hazardous Waste Cleanup - Model Toxics Control Act (Chapter 70.105D RCW) establishes requirements for the identification, investigation, and cleanup of facilities where hazardous substances have come to be located as codified in Chapter 173-340 WAC.

- Requirements of the State of Washington for water well construction as set forth in Chapter 18.104 RCW (Water Well Construction) and codified in Chapter 173-160 WAC (Minimum Standards for Construction and Maintenance of Wells), establishes criteria for the construction of extraction and compliance monitoring wells. Criteria for Class V reintroduction wells are set forth in Chapter 90.48 RCW and codified in Chapter 173-218 WAC.

- The State of Washington has established requirements for control of fugitive dusts and other air emissions during excavation and cleanup related activities, as codified in WAC 173-400-040.

- The State of Washington has established safe operating procedures and requirements for hazardous waste operations conducted at uncontrolled hazardous waste sites, as set forth in WAC 296-62 (Part P).

- Federal Clean Water requirements for discharge of treatment system effluent to the waters of the United States, as set forth in 40 CFR 122, establish design standards for wastewater treatment units.

- Water Pollution Control Act (Chapter 90.48 RCW) and Water Resources Act of 1971 (Chapter 90.54 RCW) require the use of all known available and reasonable methods (AKARMs) for controlling discharges to surface water and groundwater. This regulation will apply to excavation activities at Site F and will require that "best management practices" be applied during these activities.

- The State of Washington Hazardous Waste Management Act (Chapter 70.105 RCW) establishes requirements for dangerous waste and extremely hazardous waste as codified in Chapter 173-303 WAC and may apply depending upon any treatment residuals created. No dangerous wastes have been identified to date.

- Federal Resource Conservation and Recovery Act (RCRA). Transport of GAC will be conducted in accordance with all applicable local, state, and federal transportation regulations. Fresh GAC transported onto the site will not be a hazardous waste and standard shipping regulations will apply. Spent GAC will be managed as a K045 hazardous waste. (K045 is the hazardous waste number assigned under RCRA for spent carbon from the treatment of wastewater containing explosives.) A limit of ten percent (10%) by weight explosives loading on the GAC to be sent off site is set in order to ensure that the GAC will not be a characteristic RCRA hazardous waste for reactivity. In addition, spent GAC will be evaluated to determine if it exhibits the toxicity hazardous waste characteristic (e.g., due to 2,4-DNT content). This evaluation will include testing if necessary. Spent GAC will be manifested and transported in accordance with all applicable regulations.

In order to ensure that the off-site thermal treatment does not contribute to present or future environmental problems, the selection of a thermal treatment facility will follow the procedures presented in Procedures for Planning and Implementing Off-Site Response Actions, 58 FR 49200, September 22, 1993.

Regeneration of spent GAC will be performed at a facility permitted to accept hazardous waste. If a specific batch of spent GAC is not accepted for thermal regeneration (due, for example, to an unacceptably high ordnance loading), it will either be used as a supplemental fuel in a cement kiln or, as a last resort, incinerated. In any case, only a facility permitted to accept hazardous waste will be used.

The selected remedy will not involve the placement of RCRA hazardous wastes on site.

Chemical-Specific ARARs

Soil and groundwater remediation activities will meet the following chemical-specific ARARs:

- State of Washington Hazardous Waste Cleanup - Model Toxics Control Act (MTCA; Chapter 70.105D RCW) establishes requirements for the identification, investigation, and cleanup of facilities where hazardous substances have come to be located as codified in Chapter 173-340 WAC. Soil and groundwater cleanup standards established under the MTCA are applicable for determining remediation areas and volumes and compliance monitoring requirements, and are relevant and appropriate for determining treatment standards.

- State of Washington Groundwater Quality Standards (WAC 173-200) are applicable chemical-specific standards for water reintroduced to the Shallow Aquifer.

- Ambient concentrations of toxic air contaminants are regulated pursuant to the State of Washington Clean Air Act (Chapter 70.94 RCW) and Implementation of Regulations for Air Contaminant Sources (Chapter 173-403 WAC).

- The State of Washington Hazardous Waste Management Act (Chapter 70.105 RCW) establishes requirements for dangerous waste and extremely hazardous waste as codified in Chapter 173-303 WAC. This regulation designates those solid wastes which are dangerous or extremely hazardous to the public health and the environment; provides surveillance and monitoring requirements for such wastes until they are detoxified, reclaimed, neutralized, or disposed of safely; and establishes the siting, design, operation, closure, post-closure, financial, and monitoring requirements for dangerous and extremely hazardous waste transfer, treatment, storage, and disposal facilities.

Location-Specific ARARs

There are no location-specific ARARs for this action.

Other Criteria, Advisories, or Guidance To-Be-Considered (TBC)

- Ecology's "Statistical Guidance for Ecology Site Managers" (August 1992), and supplements to it (e.g., August 1993), as well as EPA's "Methods for Evaluating the Attainment of Cleanup Standards" (July 1992) are TBC guidance for monitoring of this remedial action.

12.3 Cost Effectiveness

The selected Remedial Action is cost-effective because it is protective of human health and the environment, achieves ARARs, and its effectiveness in meeting the objectives of the selected remedial action is proportional to its cost. The soil remediation component of the selected remedy is substantially more cost-effective than excavating all contaminated soils, while achieving the same substantive risk reduction. The selected remedy can be implemented in the short-term.

12.4 Utilization of Permanent Solutions and Alternative Treatment Technologies or Resource Recovery Technologies to the Maximum Extent Practicable

The Navy, the State of Washington, and the EPA have determined that the selected remedy represents the maximum extent to which permanent solutions and treatment technologies can be used in a cost-effective manner for Site F. Biological treatment of contaminated soils is an innovative treatment technology that will result in the on-site destruction of contaminants in the selected remedy. In addition, reintroduction of the extracted and treated groundwater will replenish the groundwater resource.

12.5 Preference for Treatment as Principal Element

By treating ordnance contaminants present in soil and groundwater media, the statutory preference for remedies employing treatment as a primary element is achieved. The selected remedy will result in on-site destruction of contaminants in both soil and groundwater.

13.0 DOCUMENTATION OF NO SIGNIFICANT CHANGES

The Navy, EPA, and Ecology released the Site F proposed plan (preferred remedial alternative) for public comment on January 21, 1994. The preferred alternative presented in the proposed plan is the same as the selected alternative presented in this Record of Decision. The Navy, EPA, and Ecology reviewed all written and verbal comments submitted during the public comment period. Upon review of those comments, it was determined that no significant changes to the remedy, as it was originally identified in the proposed plan, were necessary.

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Table 1 – Summary of Chemicals of Concern for Site F

Compound Name	Range of Soil Concentrations in mg/kg	Range of Groundwater Concentrations in $\mu g/L$
1,3,5-Trinitrobenzene	0.004 U to 17	0.022 U to 1,000
1,3-Dinitrobenzene	0.004 U to 0.27	0.026 U to 61 J
2,4,6-Trinitrotoluene	0.002 U to 1,500 J	0.008 U to 1,800,000 J
2,4-Dinitrotoluene	0.002 U to 3.6	0.018 U to 540
2,6-Dinitrotoluene	0.002 U to 0.41	0.001 U to 44 J
RDX	0.005 U to 20	0.011 U to 7,120 J
Manganese	0.15 to 0.35	2.4 to 809
Nitrate + Nitrite	0.54 U to 17	30 to 94,000

U - Not detected at indicated detection limit.
J - Estimated concentration.

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Table 2 - Basis for Selecting Exposure Pathways for Quantitative Risk Assessment

Potential Receptors	Affected Media	Route of Exposure to Chemicals in Affected Media	Pathway Selected for Quantitative Evaluation	Basis for Selection or Exclusion
RME Residents (Reasonable Maximum Exposure Scenario - people living at the site and using groundwater and other environmental resources in the area.)	Air - vapors	Inhalation	No	Chemicals do not readily volatilize.
	Air - Windblown Dust	Inhalation	Yes	Residents may inhale chemicals adsorbed to windblown dust which are released from disturbed contaminated surface soils.
	Surface Soil	Ingestion	Yes	Residents may have access to contaminated surface soils.
		Dermal Contact	Yes	Residents may have access to contaminated surface soils.
	On-site Surface Water	Ingestion	No	On-site surface water, which only ponds temporarily in the wet season, is of insufficient quantity for use as drinking water.
		Inhalation	No	Insignificant exposure pathway. Limited quantity of water exists only in the wet season and chemicals of potential concern are not volatile.
		Dermal Contact	No	Insignificant exposure pathway. Limited quantity of water exists only in the wet season and cool temperatures will minimize exposure.
	On-Site Groundwater	Ingestion	Yes	Residents may drink water from future wells completed on-site in the shallow aquifer.
		Inhalation	No	No volatile chemicals were identified. Per EPA Region 10 Supplemental Risk Assessment Guidance for superfund (Aug. 16, 1991), no chemicals were identified in groundwater with H > 10^{-4} and MW < 200.
		Dermal Contact	Yes	Chemicals may be absorbed through skin when groundwater is used for bathing.
	Off-Site Surface Water Seeps	Ingestion	No	Although off-site, downgradient surface water seeps have been used as a drinking water source in the past, chemical concentrations and resultant risk via this pathway are considerably lower than the on-site groundwater pathway summarized above (and retained for quantitative evaluation).
		Inhalation	No	Insignificant exposure pathway. Compared with on-site air exposures, chemical concentrations and exposure frequencies are much less.
		Dermal Contact	No	Insignificant exposure pathway. Compared with on-site soil exposures, chemical concentrations and exposure frequencies are much less.
		Aquatic Organism Ingestion	Yes	Existing fish habitat is extremely limited in the seep discharge area. Pathway was retained to assess risks associated with possible future habitat improvement.
		Terrestrial Organism Ingestion	No	Insufficient consumption of local terrestrial organisms occurs to warrant an investigation of this pathway. No evidence that ordnance chemicals accumulate in plants or terrestrial animals.
	Water and Soil in Vadose Zone	None	Yes	Residents may have access to contaminated soils less than 15 feet below ground surface.

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Table 3 - Inhalation of Chemicals in Air by Potential Residents

Equation:

$$Intake\ (mg/kg\text{-}day) = \frac{CAxIRxEFxED}{BWxATxCF}$$

Values for equation variables:

Exposure Factor	Units	Average Condition[a]	RME Condition[a]
Chemical Concentration Air - soil dust (CA)	mg/m^3	Calculated Value[b]	Calculated Value[c]
Inhalation Rate (IR)	m^3/day	20	20
Exposure Frequency (EF)	days/year	275	350
Exposure Duration (ED)	years	9	30
Body Weight (BW)	kg	70	70
Averaging Time (AT):			
noncarcinogenic effects	years	9	30
carcinogenic effects	years	70	70
Correction Factors (CF)	days/year	365	365

Notes:

[a] Exposure factors for the average and RME exposure scenarios obtained from EPA Region 10 Supplemental Risk Assessment Guidance for Superfund, August 16, 1991.

[b] Average concentrations of validated surface soil data for samples collected in the overflow ditch area, in conjunction with models as discussed for reference c.

[c] Upper 95th percent confidence interval concentrations about the average of validated surface soil samples collected in the overflow ditch area, in conjunction with environmental chemical transport models presented in Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites (EPA/600/8-85-002). The model addresses fugitive dust emissions within the 0.1 acre contaminated area.

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Table 4 - Ingestion of Chemicals in Soil by Potential Residents

Equation:

$$Intake\ (mg/kg\text{-}day) = \frac{CSxIR1xCFAxEFxED1}{BW1xATxCFB} + \frac{CSxIR2xCFAxEFxED2}{BW2xATxCFB}$$

Values for equations variables:

Exposure Factor	Units	Average Condition[a]	RME Condition[a]
Chemical Concentration Soil (CS)	mg/kg	Average Concentration[b]	95% UCL Concentration[b]
Ingestion Rate:	mg/day		
Child (0-6 yrs) (IR1)		0	200
Adult (IR2)		100	100
Conversion Factor A (CFA)	kg/mg	10^{-6}	10^{-6}
Exposure Frequency (EF)	day/yr	275	350
Exposure Duration:	year		
Child (0-6 yrs) (ED1)		0	6
Adult (ED2)		9	24
Body Weight:	kg		
Child (0-6 yrs) (BW1)		-	15
Adult (BW2)		70	70
Averaging Time (AT):	year		
non-carcinogenic effects		9	30
carcinogenic effects		70	70
Correction Factor B (CFB)	day/year	365	365

a. Exposure factors for the average and RME scenarios are obtained from EPA Region 10 Supplemental Risk Assessment Guidance for Superfund, August 16, 1991.

b. Average and upper 95th percent confidence interval concentrations about the average of validated data for surface soil samples.

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Table 5 - Dermal Contact and Subsequent Absorption of Chemicals in Soil by Potential Residents

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CSxSA1xCFAxAFxABSxEFxED1}{BW1xATxCFB} + \frac{CSxSA2xCFAxAFxABSxEFxED2}{BW2xATxCFB}$$

Values for equations variables:

Exposure Factor	Units	Average Condition[a]	RME Condition[a]
Chemical Concentration Soil (CS)	mg/kg	Average Concentration[b]	95% UCL Concentration[b]
Skin Surface Area Available for Contact Child (0-6 yrs) (SA1) Adult (SA2)	mg/day	 0 1900	 3,900 3,450
Conversion Factor A (CFA)	kg/mg	10^{-6}	10^{-6}
Soil/Skin Adherence Factor (AF)	mg/cm^2	1.0	1.0
Absorption Factor (ABS): metals organics	% by wt.	 0[d] 50[e]	 0[d] 50[e]
Exposure Frequency (EF)	day/yr	275	350
Exposure Duration: Child (0-6 yrs; ED1) Adult (ED2)	year	 0 9	 6 24
Body Weight: Child (0-6 yrs; BW1) Adult (BW2)	kg	 - 70	 15 70
Averaging Time (AT): non-carcinogenic effects carcinogenic effects	year	 9 70	 30 70
Correction Factor B (CFB)	day/year	365	365

a. Exposure factors for the average and RME scenario are obtained from EPA Region 10 Supplemental Risk Assessment Guidance for Superfund, August 16, 1991.
b. Average and upper 95th percent confidence interval concentrations about the average of validated data for surface soil samples.
c. Average for summer (5,000 cm^2) and winter (1900 cm^2) RME exposure factors.
d. Cadmium has an absorption factor of 1%.
e. An upper-bound default dermal absorption was assumed based on Hurst (1991), which is also consistent with model predictions using EPA Region 10 Supplemental Risk Assessment Guidance for Superfund.

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Table 6 - Ingestion of Chemicals in Drinking Water by Potential Residents

Equation:

$$Intake\ (mg/kg\text{-}day) = \frac{CWxIRxEFxED}{BWxATxCF}$$

Values for equation variables:

Exposure Factor	Units	Average Condition[a]	RME Condition[a]
Chemical Concentration in Water (CW)	mg/liter	Average Concentration[b]	95% UCL Concentration[b]
Ingestion Rate (IR)	liters/day	1.4	2.0
Exposure Frequency (EF)	days/year	275	350
Exposure Duration (ED)	years	9	30
Body Weight (BW)	kg	70	70
Averaging Time (AT): noncarcinogenic effects carcinogenic effects	years years	9 70	30 70
Correction Factor (CF)	days/year	365	365

Notes:

[a] Exposure factors for the average and RME exposure scenarios obtained from EPA Region 10 Supplemental Risk Assessment Guidance for Superfund, August 16, 1991.

[b] Validated data used to determine average and RME groundwater concentrations for samples collected at Well F-MW31.

394703\Table.6

Table 7 - Dermal Absorption of Chemicals in Water by Potential Residents

Equation:

$$Intake\ (mg/kg\text{-}day) = \frac{CWxSAxPCxETxEFxEDxCFA}{BWxATxCFB}$$

Values for equation variables:

Exposure Factor	Units	Average Condition[a]	RME Condition[b]
Chemical Concentration Water (CW)	mg/L	Average Concentration[b]	95% UCL Concentration[b]
Conversion Factor A (CFA)	liters/cm^3	10^{-3}	10^{-3}
Skin Surface Area Available for Contact (SA)	cm^2	20,000	20,000
Dermal Permeability Constant (PC):			
metals	cm/hr	0	0
ordnance and other organics	cm/hr	calculated value[c]	calculated value[c]
Exposure Time (ET)	hours/day	0.12	0.17
Exposure Frequency (EF)	days/year	275	350
Exposure Duration (ED)	years	9	30
Body Weight (BW)	kg	70	70
Averaging Time (AT):			
noncarcinogenic effects	years	9	30
carcinogenic effects	years	70	70
Correction Factor B (CFB)	days/year	365	365

Notes:

[a] Exposure factors for the average and reasonable maximum exposure scenarios obtained from EPA Region 10 Supplemental Risk Assessment Guidance for Superfund, August 16, 1991.

[b] Validated data used to determine average and RME groundwater concentrations for samples collected at Well F-MW31.

[c] Calculated based on EPA Region 10 Supplemental Risk Assessment Guidance for Superfund.

394703\TABLE.7

Table 8 - Ingestion of Chemicals in Fish/Shellfish by Potential Recreational Users

Equation:

$$\textit{Intake (mg/kg-day)} = \frac{CSW x BCF x FCR x FDF x ED}{BW x AT x CFA x CFB}$$

Values for equations variables:

Exposure Factor	Units	Average Condition[a]	RME Condition[a]
Chemical Concentration Surface water (CSW)	µg/L	Average Conc.[b]	95% UCL Conc.[b]
Bioconcentration Factor (BCF)	unitless	Chemical Specific[c]	Chemical Specific[c]
Fish Consumption Rate (FCR)	g/day	6.5[d]	54[e]
Fish Diet Fraction (FDF)	unitless	0.5[f]	0.5[f]
Exposure Duration (ED)	years	9	30
Body Weight (BW)	kg	70	70
Average Time (AT): non-carcinogen carcinogen	year	 9 70	 30 70
Correction Factor A (CFA)	µg/mg	1,000	1,000
Correction Factor B (CFB)	g/L	1,000	1,000

a. Exposure factors for the average and RME scenario are obtained from EPA Region 10 Supplemental Risk Assessment Guidance for Superfund, August 16, 1991.

b. Average and upper 95th percent confidence interval concentrations based on contaminant transport modeling.

c. See Table 7-8 in Site F RI/FS.

d. Based on Section 304 of Clean Water Act.

e. Based upon EPA (1991d) "Standard Default Exposure Factors".

f. Based on Chapter 173-340-730 WAC, which establishes regional exposure factors for fish consumption.

394703\Table.8

Table 9 - Fish Bioconcentration Factors for Chemicals of Potential Concern

Chemical	BCF	Reference
Barium	-	No Data
Beryllium	19	IRIS
Cadmium	64	IRIS
Chromium	16	IRIS
Copper	36	IRIS
Cyanide	1	IRIS
Manganese	-	No Data
Mercury	5500	IRIS (freshwater)
Nickel	47	IRIS
Nitrate	-	No Data
Nitrite	-	No Data
Silver	0.5	IRIS
Zinc	47	IRIS
RDX	2.9	Geometric Mean of BCFs reported by Etnier, 1986.
2,4,6-TNT	9.5	Value for fish muscle reported by Liu et al., 1983.
2,4-DNT	3.8	IRIS
1,3,5-TNB	3.0	Based on log K_{ow} regression.[a]
1,3-DNB	6.0	Based on log K_{ow} regression.[a]
Nitrobenzene	2.9	IRIS
2,4-DNP	1.5	EPA, 1992a

Notes:

IRIS: Integrated Risk Information System, March 1991.

a. From Layton et al. (1987). Conventional Weapons Demilitarization: A Health and Environmental Effects Database Assessment. Lawrence Livermore National Laboratory, University of California - Berkeley. Supported by U.S. Army Medical Research and Development Command.

394703\TABLE.9

Table 10 – Reference Doses for Chemicals of Potential Concern

	Oral Exposures					Inhalation Exposures				
Chemical	Reference Dose in mg/kg-day	Uncertainty Factor	Species Tested	Target Organ/Effect	Reference	Reference Dose in mg/kg-day	Uncertainty Factor	Species Tested	Target Organ/Effect	Reference
Metals and Inorganics										
Aluminum	ND					ND				IRIS
Barium	7.0E-02	3	human	hypertension	IRIS	1.0E-04	1,000	rat	fetotoxicity	HEAST
Beryllium	5.0E-03	100	rat	no effect	IRIS	ND				IRIS
Cadmium (water)	5.0E-04	10	human	renal proteinuria	IRIS	ND				IRIS
Cadmium (food)	1.0E-03	10	human	renal proteinuria	IRIS	ND				IRIS
Chromium III	1.0E+00	100	rat	no effect	IRIS	5.7E-07	300	rat	nasal mucosa atrophy	HEAST '91 (a)
Chromium VI	5.0E-03	500	rats	no effect	IRIS	5.7E-07	300	rat	nasal mucosa atrophy	HEAST '91 (a)
Copper	3.7E-02	NA	human	G.I. Irritation	HEAST	ND				IRIS
Lead	ND				IRIS	ND				IRIS
Manganese	5.0E-03	1	human	central nervous system	IRIS	1.1E-04	300	human	respiratory, psychomotor	IRIS
Mercury	3.0E-04	1,000	rat	kidney	HEAST	9.0E-05	30	human	neurotoxicity	HEAST
Nickel	2.0E-02	300	rat	decreased body/organ weight	IRIS	ND				IRIS
Silver	5.0E-03	3	human	skin discoloration	IRIS	ND				IRIS
Zinc	2.0E-01	10	human	anemia	IRIS	ND				IRIS
Cyanide	2.0E-02	100	rat	wt. loss, thyroid, myelin	IRIS	ND				IRIS
Nitrite	1.0E-01	1	human	infant blood	IRIS	ND				IRIS
Nitrate	1.6E+00	1	human	infant blood	IRIS	ND				IRIS
Ordnance										
RDX	3.0E-03	100	rat	prostate	IRIS	ND				
2,4,6-TNT	5.0E-04	1,000	dog	liver	IRIS	ND				
2,4-DNT	2.0E-03	100	dog	neurotoxicity	IRIS	ND				
2,6-DNT	ND	ND	ND	ND	IRIS	ND				
1,3,5-TNB	5.0E-05	10,000	rat	spleen	IRIS	ND				
1,3-DNB	1.0E-04	3,000	rat	spleen	IRIS	ND				
Nitrobenzene	5.0E-04	10,000	rat, mouse	blood, kidney, liver, adrenal	IRIS	5.7E-04	3,000	mouse	blood, kidney, liver, adrenal	HEAST
Picramic Acid	ND				IRIS	ND				IRIS
Picric Acid	ND				IRIS	ND				IRIS
Tetryl	ND				IRIS	ND				IRIS
Other Organics										
2,4-Dinitrophenol	2.0E-03	1,000	human	eye cateracts	IRIS	ND				
Di-n-octylphthlate	2.0E-02	1,000	rat	liver, kidney	HEAST	ND				

ND Not yet determined by the EPA.
a) The inhalation RfDs for chromium were removed from HEAST (1992).
HEAST: Health Effects Assessment Summary Tables, 1992.
IRIS: Integrated Risk Information System, March 1991.

394703\Table10.wk1

Table 11 - Slope Factors for Chemicals of Potential Concern

Chemical	Cancer Group	Oral Exposures			Inhalation Exposures			Reference
		Slope Factor (mg/kg-day)-1	Species Tested	Target Organ	Slope Factor (mg/kg-day)-1	Species Tested	Target Organ	
Metals and Inorganics								
Aluminum	NE	NA			NA			
Barium	NE	NA			NA			
Beryllium	B2	4.3E+00	rat	total body	8.40E+00	human	lung	IRIS
Cadmium	B1	NA			6.1E+00	human	respiratory tract	IRIS
Chromium III	NE	NA			NA			
Chromium VI	A	NA			4.2E+01	human	lung	IRIS
Copper	D	NA			NA			IRIS
Lead	B2	NA			NA			IRIS
Manganese	D	NA			NA			IRIS
Mercury	D	NA			NA			IRIS
Nickel (refinery dust)	A	NA			8.40E-01	human	respiratory tract	HEAST
Silver	D	NA			NA			IRIS
Zinc	D	NA			NA			IRIS
Cyanide	D	NA			NA			IRIS
Nitrite	NE	NA			NA			IRIS
Nitrate	NE	NA			NA			IRIS
Ordnance								
RDX	C	1.1E-01	mouse	liver	NA			IRIS
2,4,6-TNT	C	3.0E-02	rat	urinary, bladder	NA			IRIS
2,4-DNT	B2	6.8E-01	rat	liver, mammary gland	NA			IRIS
2,6-DNT	B2	6.8E-01	rat	liver, mammary gland	NA			IRIS
1,3,5-TNB	NE	NA			NA			
1,3-DNB	NE	NA			NA			
Nitrobenzene	D	NA			NA			
Picramic Acid	NE	NA			NA			
Picric acid	NE	NA			NA			
Tetryl	NE	NA			NA			
Other Organics								
2,4-Dinitrophenol	NE	NA			NA			
Di-n-octylphthlate	NE	NA			NA			

Notes:
B2 Probable human carcinogen.
C Possible human carcinogen.
D No classifiable as to human carcinogenicity.
NE Not yet evaluated for carcinogenicity by EPA.
NA Not applicable, not evaluated by EPA, and/or not a carcinogen.
HEAST: Health Effects Assessment Summary Tables, 1992.
IRIS: Integrated Risk Information System, March 1991.

394703\Table11.wk1

Table 12 - Calculated Hazard Quotients for Site F Baseline Exposure Assumptions

	Dust Inhalation		Soil Ingestion		Dermal Contact		Water Ingestion		Water Contact		Fish Ingestion		Cumulative Hazard Index	
	Average	RME	Average	RME	Average	RME	Average	RME	Average	RME	Average	RME	Average	RME
Metals and Inorganics														
Barium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Copper	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cyanide	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.2	<0.1	<0.1	<0.1	<0.1	0.1	0.2
Lead	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese	<0.1	<0.1	0.1	0.3	<0.1	<0.1	0.9	1.7	<0.1	<0.1	<0.1	<0.1	1.0	2.0
Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate-N	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.7	4.5	<0.1	<0.1	<0.1	<0.1	1.7	4.5
Nitrite-N	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.0	2.2	<0.1	<0.1	<0.1	<0.1	1.0	2.2
Silver	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ordnance														
RDX	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	2	9	<0.1	0.1	<0.1	<0.1	2	9
2,4,6-Trinitrotoluene	<0.1	<0.1	0.9	7	15	88	187	510	5.0	13.0	0.2	0.6	208	618
2,4-Dinitrotoluene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	3	8	0.2	0.4	<0.1	<0.1	4	8
2,6-Dinitrotoluene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1
1,3,5-Trinitrobenzene	<0.1	<0.1	<0.1	0.1	0.2	0.9	72	170	2.0	5.5	<0.1	0.1	75	176
1,3-Dinitrobenzene	<0.1	<0.1	<0.1	<0.1	<0.1	0.5	5	17	0.1	0.4	<0.1	<0.1	5	18
Nitrobenzene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Otto Fuel	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Picramic Acid	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Picric Acid	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Tetryl	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Semivolatile Organics														
2,4-Dinitrophenol	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Di-n-octyl phthalate	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TOTAL HAZARD INDEX	<0.1	<0.1	0.9	8	15	89	273	721	7	19	0.2	0.7	297	838

394703\Table12.wk1

Table 13 - Calculated Lifetime Cancer Risks for Site F Baseline Exposure Assumptions

	Dust Inhalation		Soil Ingestion		Dermal Contact		Water Ingestion		Water Contact		Fish Ingestion		CUMULATIVE CANCER RI	
	Average	RME	Average	RME	Average	RME	Average	RME	Average	RME	Average	RME	Average	RME
Metals and Inorganics														
Barium														
Cadmium	6E-10	3E-09	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	6E-10	3E-09
Chromium	1E-07	4E-07	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	1E-07	4E-07
Copper														
Cyanide														
Lead														
Manganese														
Mercury														
Nickel	3E-09	1E-08	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	3E-09	1E-08
Nitrate-N														
Nitrite-N														
Silver														
Zinc														
Ordnance														
RDX	2E-10	6E-10	8E-08	3E-06	1E-06	4E-05	9E-05	1E-03	7E-07	9E-06	9E-07	8E-06	9E-05	1E-03
2,4,6-Trinitrotoluene	4E-09	9E-09	2E-06	5E-05	3E-05	6E-04	4E-04	3E-03	9E-06	8E-05	4E-07	4E-06	4E-04	4E-03
2,4-Dinitrotoluene	3E-11	8E-11	2E-08	4E-07	3E-07	5E-06	2E-05	3E-04	8E-07	9E-06	2E-08	2E-07	3E-05	3E-04
2,6-Dinitrotoluene	1E-10	2E-10	5E-08	1E-06	8E-07	1E-05	6E-04	4E-03	3E-05	2E-04	4E-07	4E-06	6E-04	5E-03
1,3,5-Trinitrobenzene														
1,3-Dinitrobenzene														
Nitrobenzene														
Otto Fuel														
Picramic Acid														
Picric Acid														
Tetryl														
Semivolatile Organics														
2,4-Dinitrophenol														
Di-n-octyl phthalate														
CUMULATIVE CANCER	1E-07	5E-07	2E-06	5E-05	3E-05	6E-04	1E-03	9E-03	4E-05	3E-04	2E-06	8E-06	1E-03	1E-02

394703\Table13.wk1

Table 14 - Summary of Assumptions and Uncertainties in the Baseline Human Health Risk Assessment
Sheet 1 of 3

Area of Uncertainty	Assumption Made	Likely Effect on Site Risk	Rationale
Selecting Inorganic Chemicals of Potential Concern	Except for arsenic, all inorganics result from spills in the disposal lagoon	Slightly Overestimated	At least some component of inorganic concentrations are from natural background. Inorganics generally pose negligible risk at Site F.
Exposure Scenario	Residential Use of Groundwater	Highly Overestimated	Water supplies at SUBASE, Bangor are derived from the Sea Level Aquifer or Deeper Aquifers, which are isolated from the Shallow Aquifer by one or more aquitards.
Dermal Absorption Rates	Values estimated based on models	Unknown	Models have not been validated for chemicals of concern at Site F.
Measured Chemical Concentrations in Water and Soil	Estimated values accurately represent true concentration	Overestimates	Measurement imprecision will result in larger upper confidence limit concentrations.
Defining Soil Concentrations Appropriate for RME Conditions	Applied sample results for surface samples collected in the 0.1-acre overflow ditch	Overestimate	High surface concentrations of site contaminants are limited to a small area of the overflow ditch. Exposure calculations based only on samples collected from this area likely overestimates the reasonable scenario.
Air Concentrations	Modeled using numerous assumptions	Overestimates	Field verification demonstrates estimated concentrations are 10x larger than actual. Conservative estimates of wind threshold, grain size, vegetative cover, and emission area size, all cause inflated estimates of dust emission.

Table 14 - Continued

Area of Uncertainty	Assumption Made	Likely Effect on Site Risk	Rationale
Derivation of Toxicity Values	Extrapolated from genetically similar populations exposed to high chemical concentrations to a diverse human population exposed to low chemical concentrations, sometimes using limited experimental data.	Unknown	Toxicity values can change as more experimental data become available.
Chromium Speciation	All identified chromium is the more toxic chromium (VI)	Slightly Overestimated	Most environmental chromium is chromium (VI). Chromium does not contribute significantly to risks at Site F.
Toxicity Values for Lead	Risk occurs at 500 to 1,000 mg/kg soil	Unknown	Additional risk from lead exposure may exist; however, lead concentrations are far below 500 to 1,000 ug/kg.
Toxicity Factors for 2,4,6-DNT, 2,4-DNT, 2,6-DNT, 1,3,5-TNB	Toxicity values based on limited studies, toxicity from dermal exposures have not been evaluated, 2,4-DNT toxicity is based on the more toxic 2,6-DNT	Overestimated	Based on limited available data, conservative methods were used to determine toxicity factors for most of the ordnance chemicals. Risk from 2,4,6-DNT, 2,4-DNT, 2,6-DNT, 1,3,5-TNB contributes strongly to total site risk.
Carcinogenic Toxicity Factor for RDX	The supporting study was of sufficient quality to establish a slope factor	Overestimated	Supporting study had a poor control group and counted both benign and malignant tumors. Risk from RDX contributes significantly to total site risk.
Dermal vs. Oral Exposures	No difference in toxicity when exposed dermally versus orally	Unknown	Insufficient knowledge concerning the mechanisms of dermal absorption to ordnance chemicals

Table 14 - Continued

Area of Uncertainty	Assumption Made	Likely Effect on Site Risk	Rationale
Model for Estimating Cancer Risk	Linear Dose-response relationship at low doses	Unknown	Insufficient scientific knowledge regarding mechanisms of toxicity at low doses.
Risks from Multiple Chemical Exposures	Risks are additive	Unknown	Insufficient knowledge of chemical interactions.
Exposure Concentration	Constant for 30 years	Overestimates	Natural chemical degradations and dispersion will reduce chemical concentrations over time.

table.14

Table 15 - Summary of Cleanup Levels for Site F

Chemical of Concern	Soil Cleanup Level in mg/kg: Direct ontact Protection(a	Soil Cleanup Level in mg/kg: Groundwater Protection(b)	Groundwater Cleanup Level in ug/L(c)	Surface Water Cleanup Level in ug/L: Protection of Aquatic Life(d)	Surface Water Cleanup Level in ug/L: Drinking Water(e)
2,4,6-TNT	33	0.3	2.9	40	2.9
RDX	9.1	1*	0.8	260	0.8
2,4- & 2,6-DNT	1.5	0.5*	0.13	300	0.13
1,3,5-TNB	4.0	0.25*	0.8	80	0.8
1,3-DNB	8.0	0.25*	1.6	No Data	1.6
Nitrate-N	29,000	1,000	10,000	10,000	10,000
Nitrite-N	8,000	100	1,000	No Data	1,000
Manganese	940	940	50	No Data	50

(a) MTCA Method B soil cleanup levels with the exception of manganese which is based on background data (refer to Site F RI/FS).

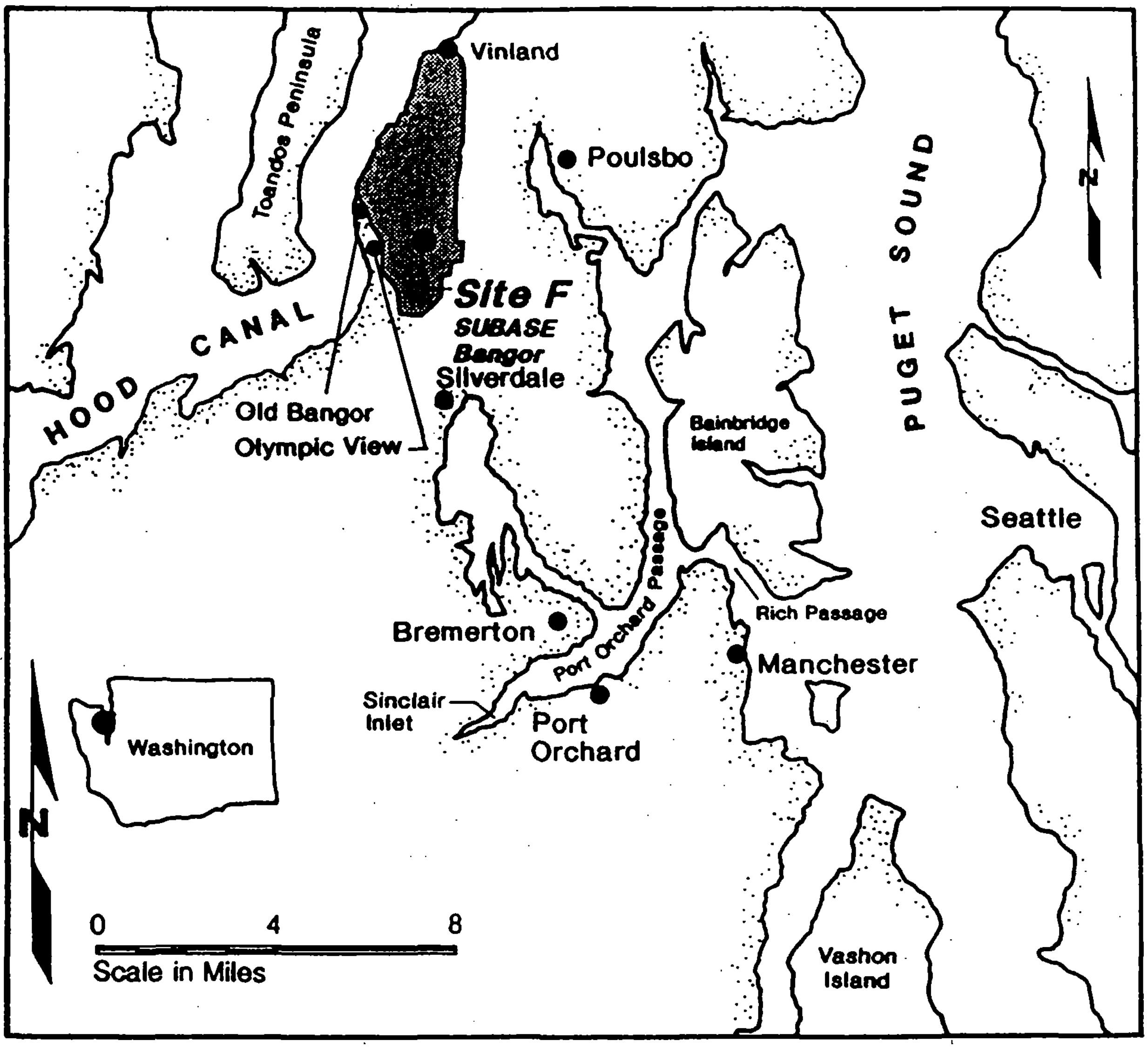
(b) Groundwater Protection soil cleanup levels developed based on data from site-specific leaching studies and and conservative site condition assumptions, with the exception of manganese which is based on background data. Cleanup levels adjusted for current Practical Quantitation Limits (PQLs) established for EPA Method 8330 (HPLC) are denoted with an asterik (*).

(c) MTCA Metohd B groundwater cleanup levels, with the exceptions of nitrate and nitrite (MCLS) and manganese (SMCL).

(d) Values for TNT, RDX, DNT, TNB, and DNB obtained from literature sources (refer to Table 7-11 in Site F RI/FS for references). Value for nitrate based on MCL.

394703\Table15.wk1

Generalized Regional Map



Note: Base map prepared from "Puget Sound Country Washington" published by kroll Map Company, undated.

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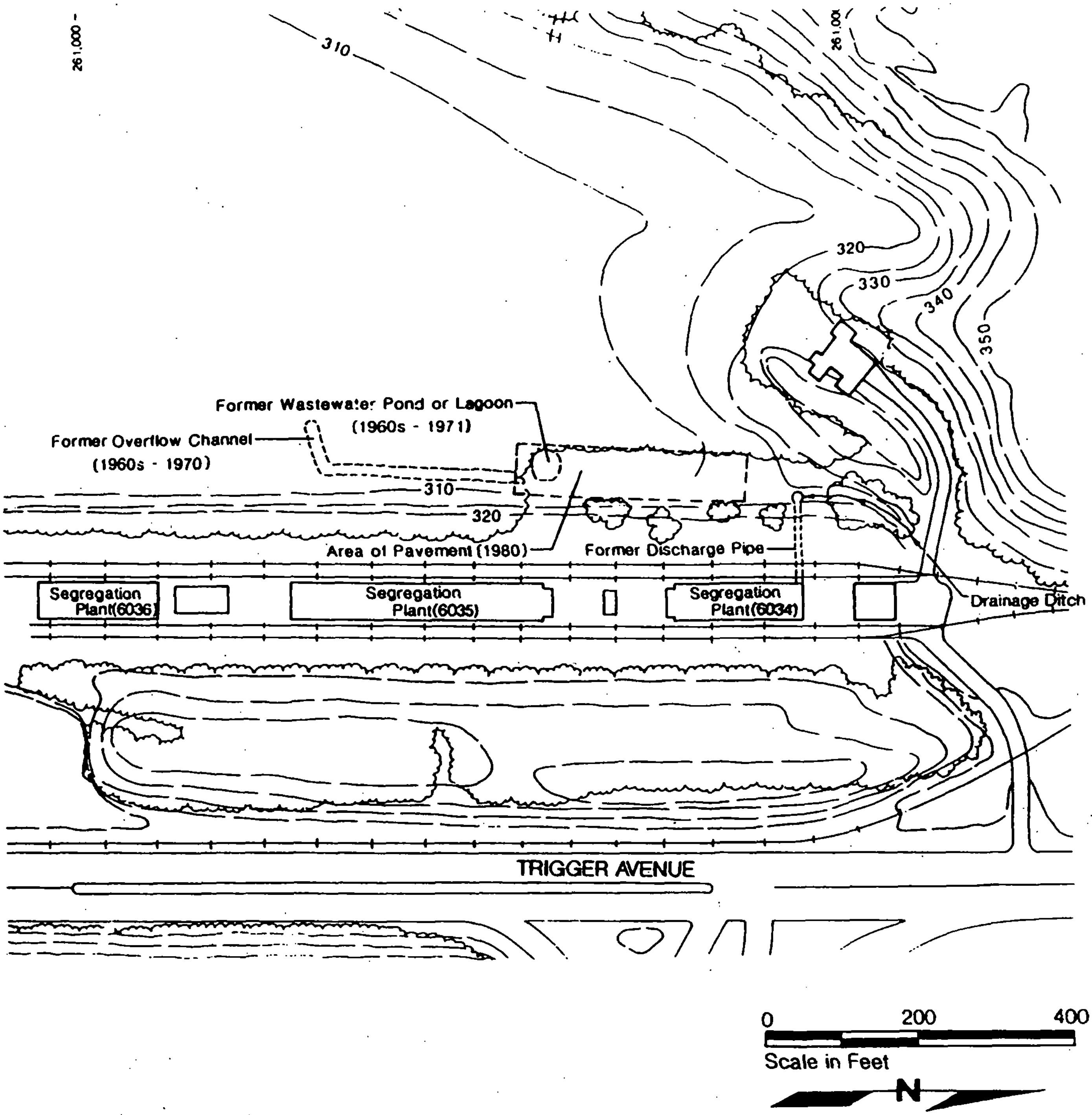
Figure 1

Site F Historical Features Map



HARTCROWSER
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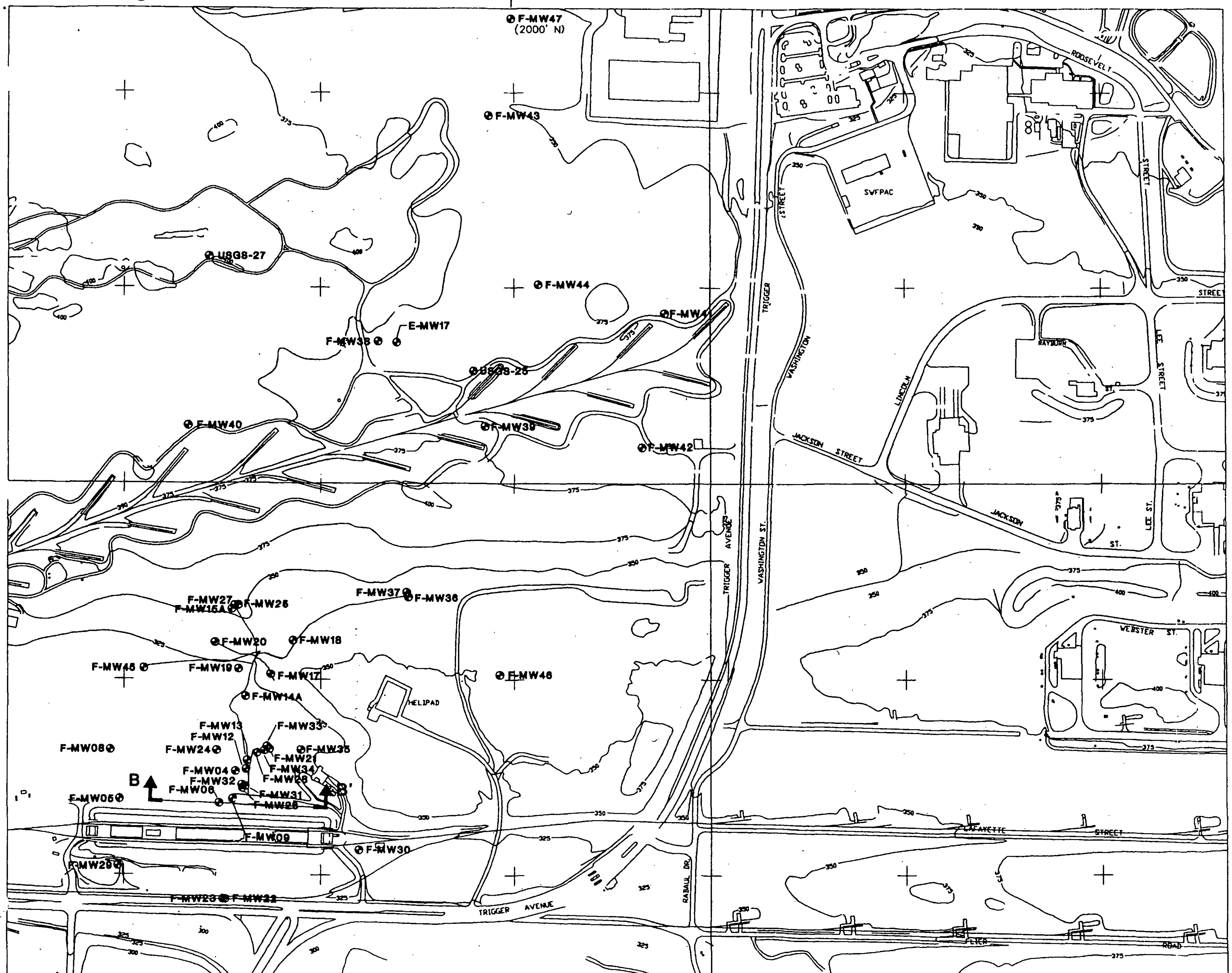
Figure 2

Monitoring Well Location Plan



F-MW26 Monitoring Well Location and Number

B B' Cross Section Location and Designation

Notes: 1. All wells are completed in the Shallow Aquifer, except F-MW47 which is completed in the Sea Level Aquifer.

0 500 1000

Scale in Feet

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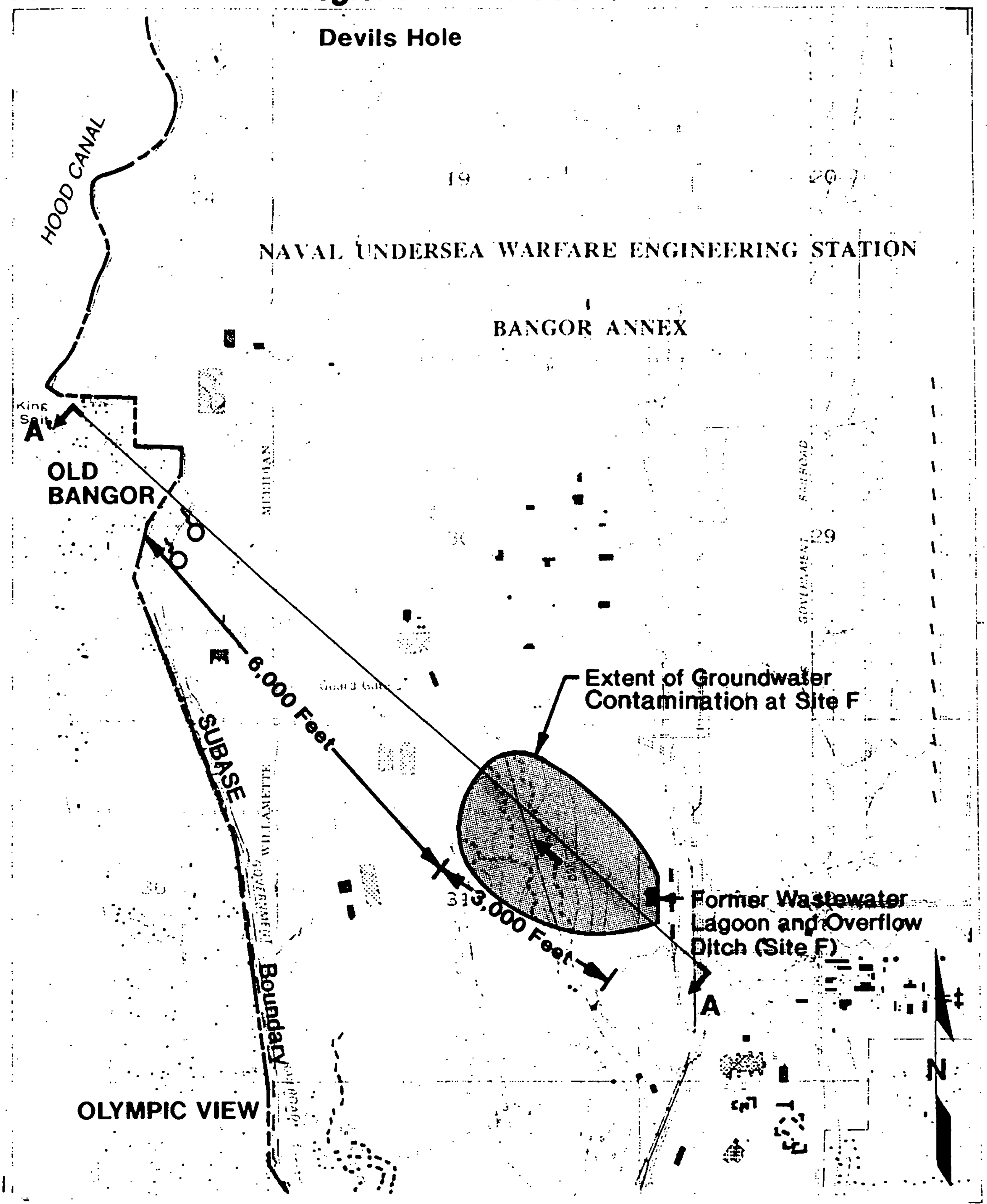
Figure 3

SUBASE, Bangor Map Showing Extent of Site F Groundwater Contamination and Regional Cross Section Location



e: Base map prepared from 7.5 minute quadrangle of Poulsbo, Washington.

A A' Regional Cross Section Location and Designation

Seep Sample Location

0 2000 4000

Approximate Scale in Feet

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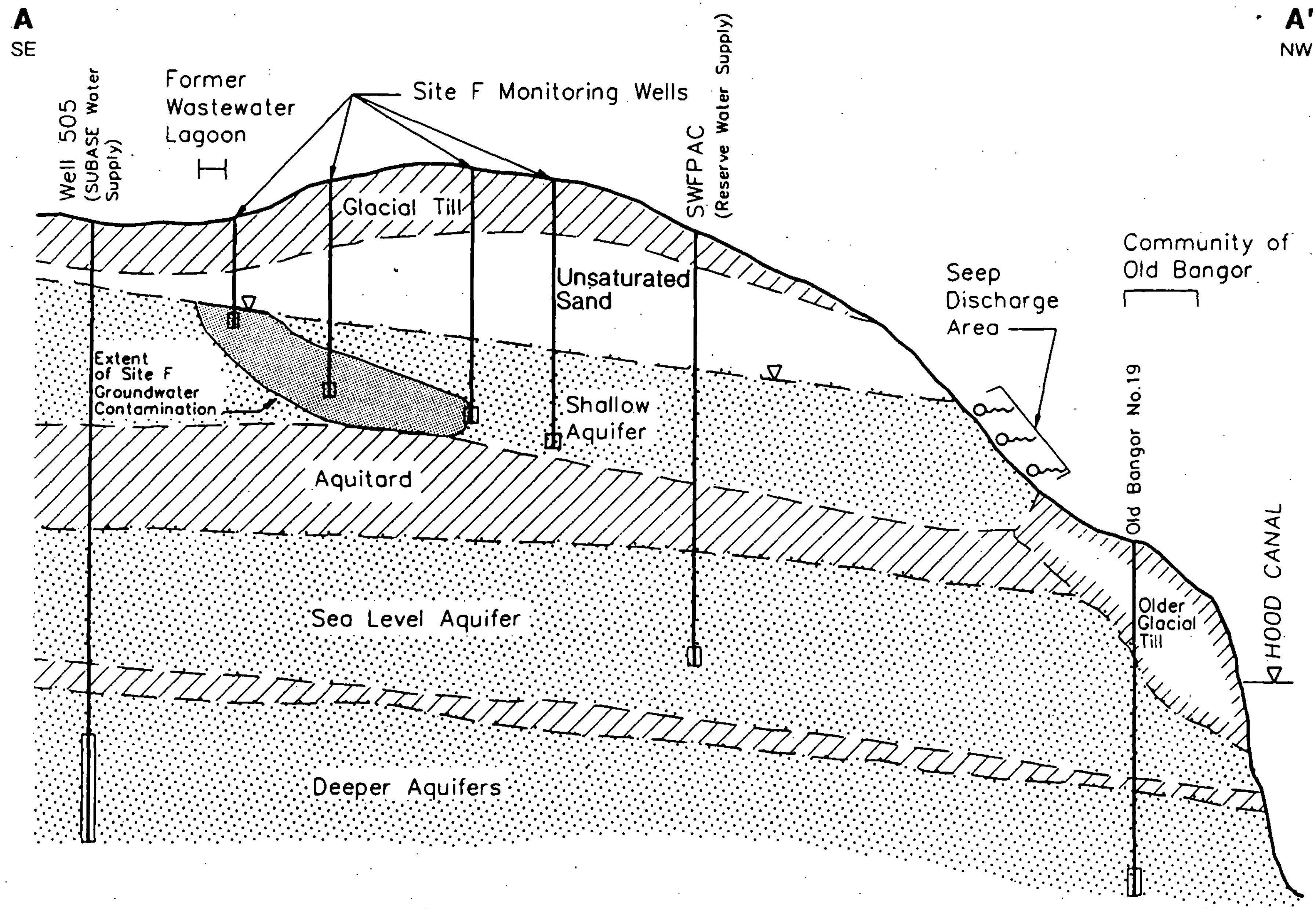
Figure 4



SWFPAC Well Number

Well Location

Screened Interval

Note: Contacts between geologic units are based upon interpolation between wells and represents our interpretation of subsurface conditions based on currently available data.

Horizontal Scale in Feet

0 2000 4000

0 100 200

Vertical Scale in Feet

Vertical Exaggeration x 20

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Figure 5

Shallow Aquifer Water Table Elevation Contour Map (April 1992)

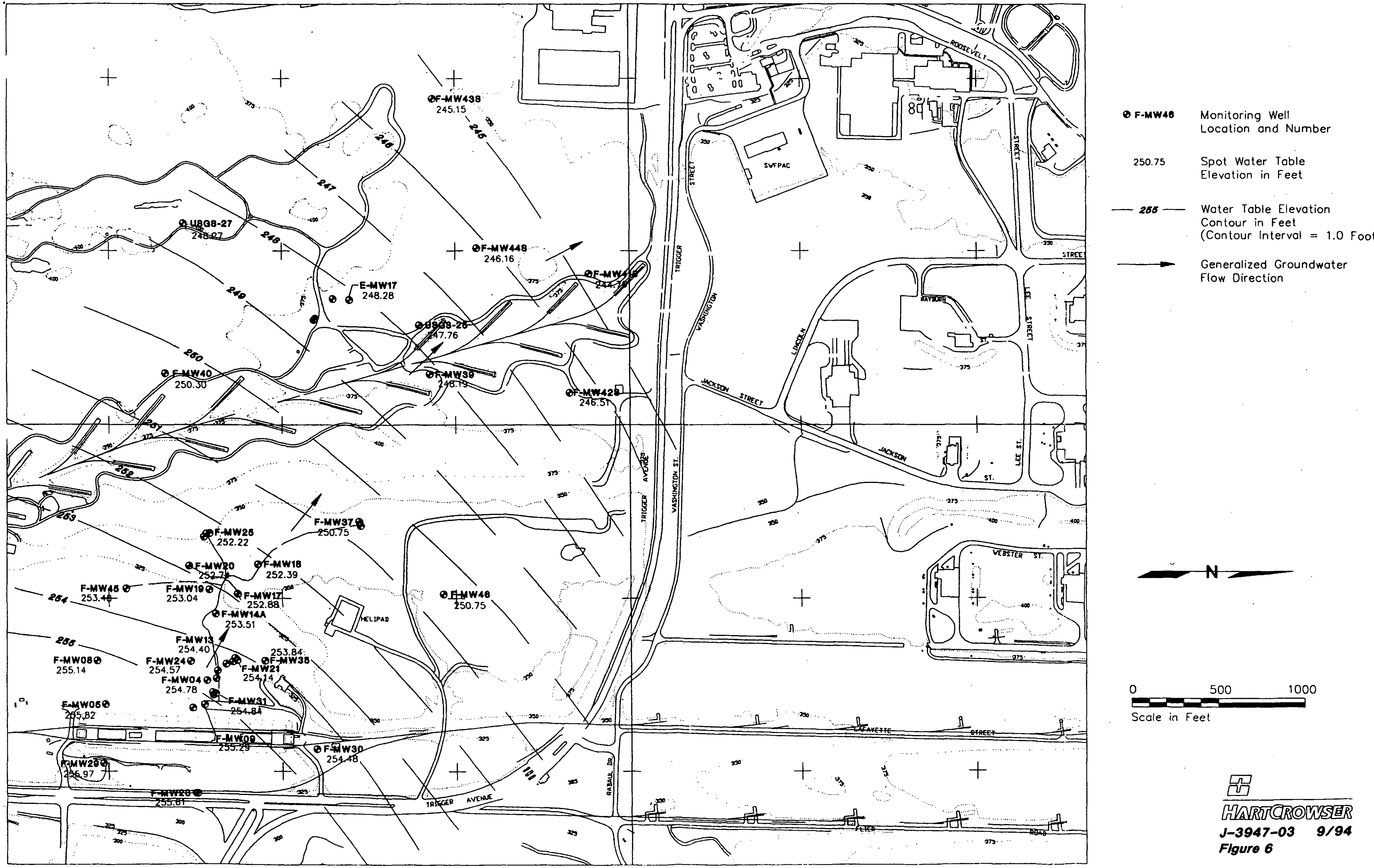

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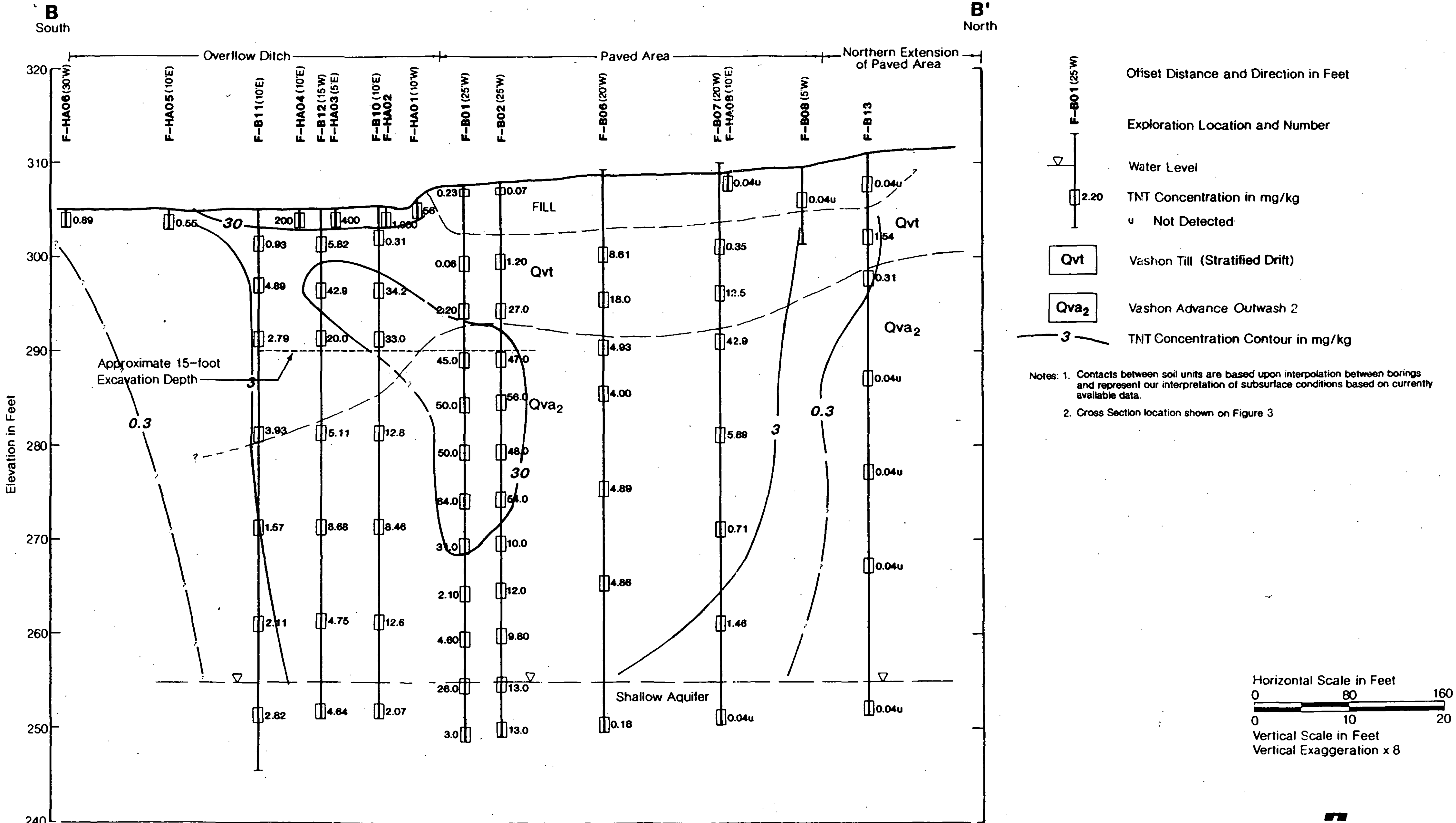
Figure 6

Vertical Distribution of TNT in Soil
Former Wastewater Lagoon and Overflow Ditch (North–South Profile)



Notes: 1. Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

2. Cross Section location shown on Figure 3

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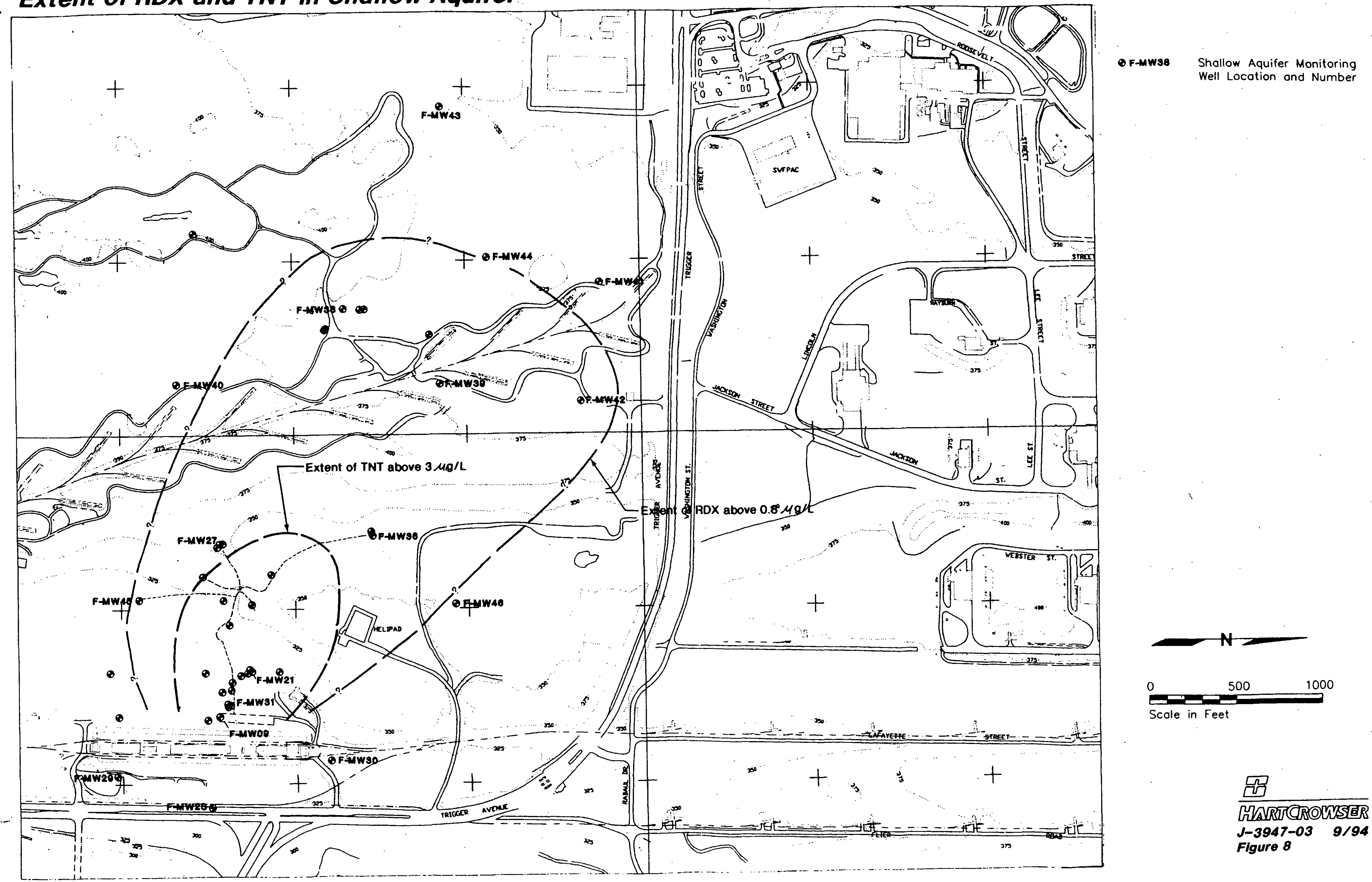
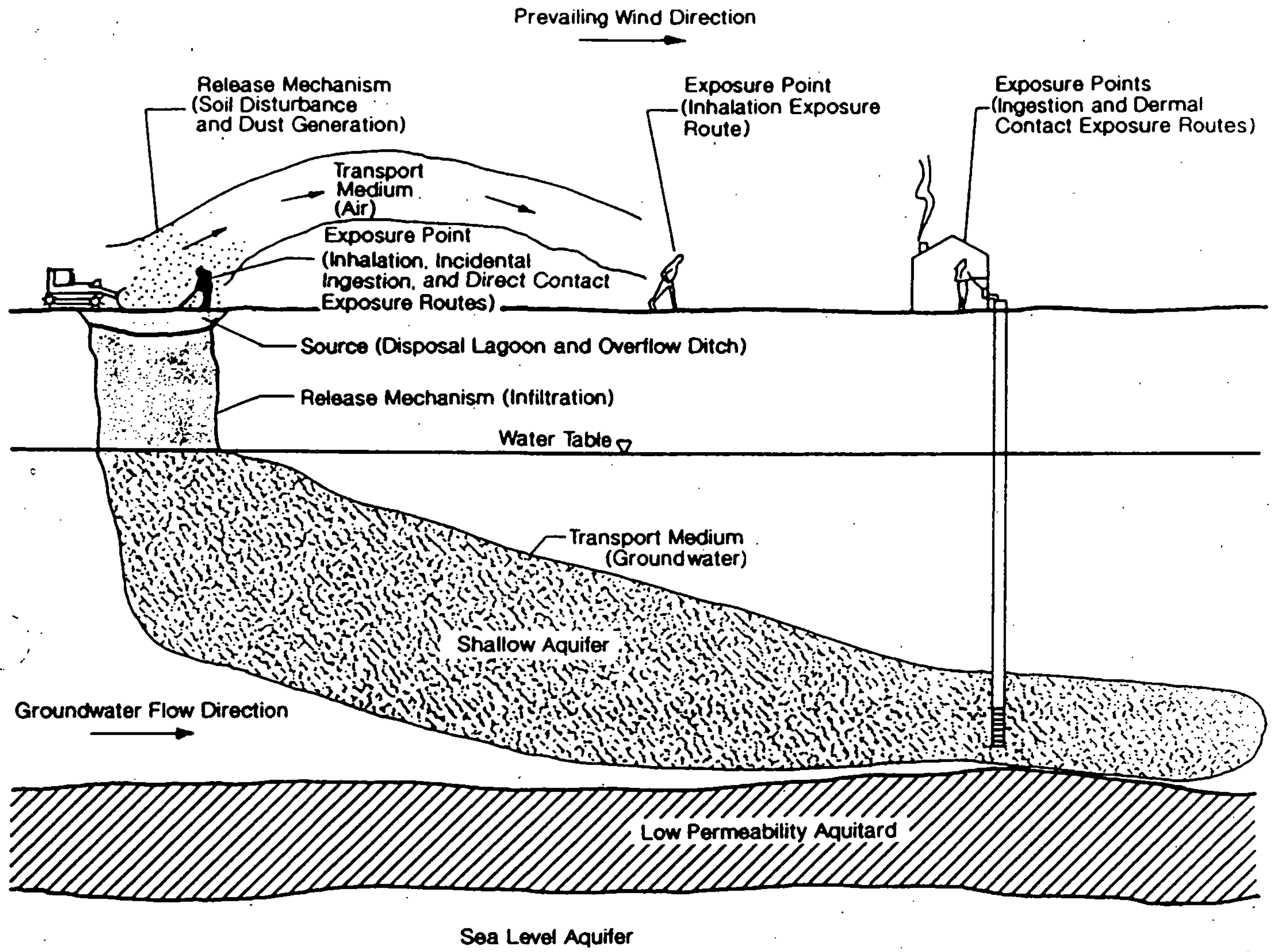
Figure 7

Extent of RDX and TNT in Shallow Aquifer



Baseline Exposure Pathways
Hypothetical On-Site Conditions



Not to Scale

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Figure 9

Exte... of Soil Above Cleanup Acti... Levels

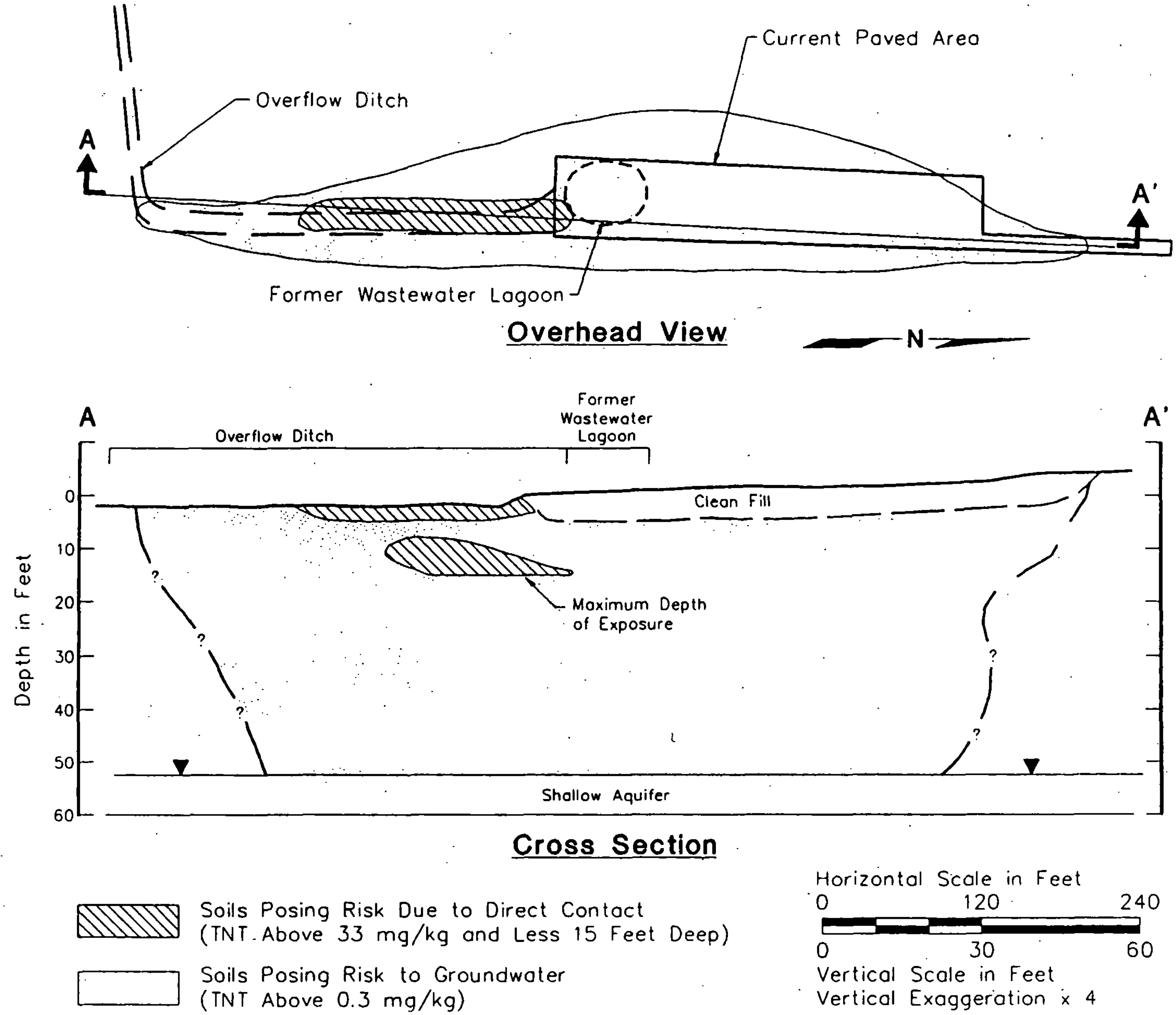

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Figure 10

Exte of Infiltration Barrier

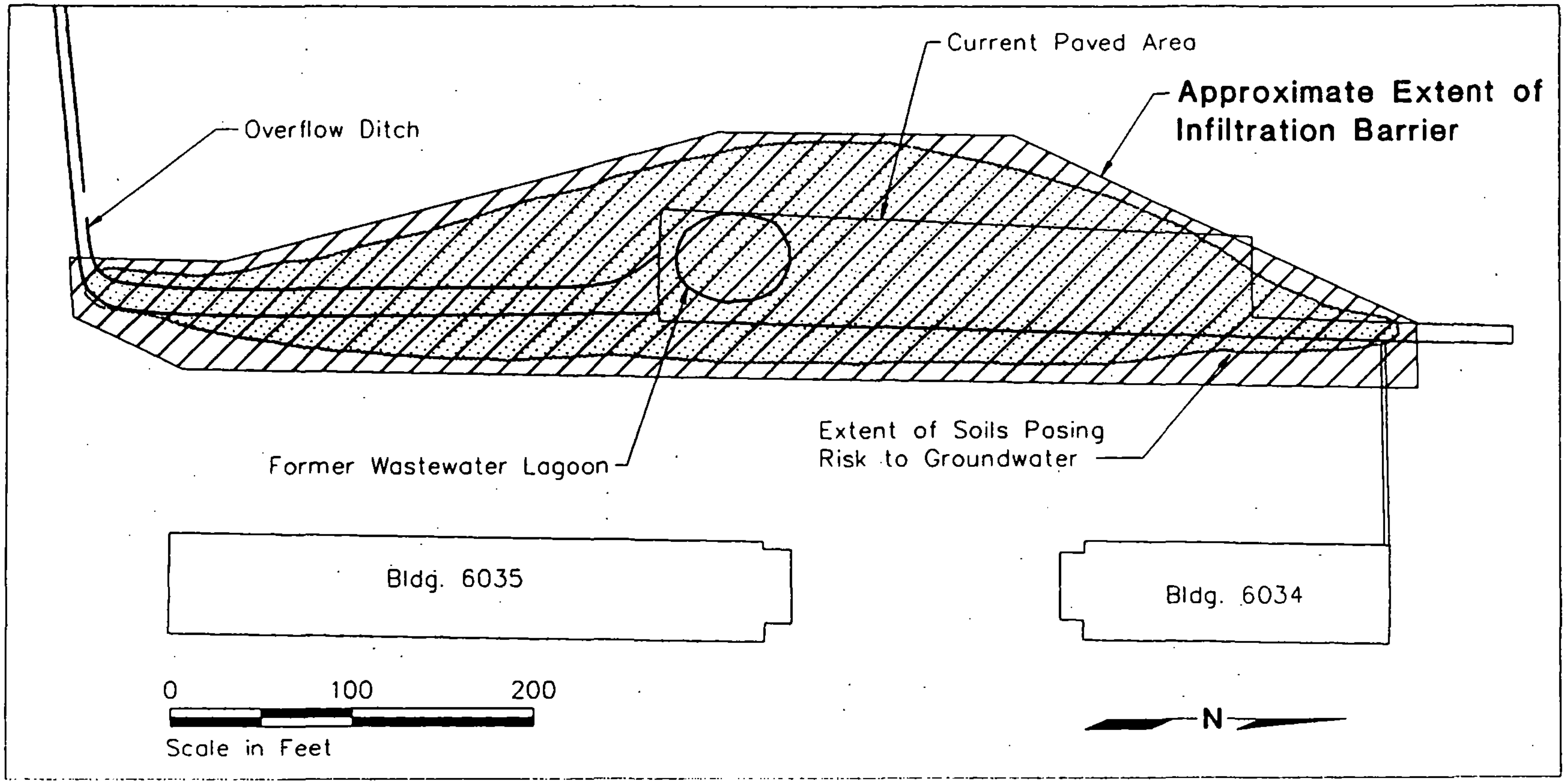

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Figure 11

ATTACHMENT A
RESPONSIVENESS SUMMARY

ATTACHMENT A
RESPONSIVENESS SUMMARY

OVERVIEW

Site F is one of several operable units at SUBASE, Bangor, which was listed on the National Priorities List (NPL) of Hazardous Waste Sites on August 30, 1990. SUBASE, Bangor is located in Kitsap County, on Hood Canal approximately 10 miles north of Bremerton, Washington. Site F is located in the southcentral portion of SUBASE, Bangor, approximately 1.5 miles east of Hood Canal.

The site received wastewaters from the demilitarization of ordnance items containing explosives. Wastewaters were discharged into an unlined lagoon and subsequently seeped into the soils and underlying groundwater.

A Remedial Investigation and Feasibility Study (RI/FS) for Site F was completed on November 12, 1993. An Interim Remedial Action is under construction at the site to reduce the movement of contaminated groundwater from the former wastewater disposal area.

This **Responsiveness Summary** addresses public comments on the Proposed Plan for Final Remedial Action at Site F. These public comments were raised during the public comment period of January 23 to February 22, 1994, and at the Public Meeting held on February 3, 1994, at the Central Kitsap Junior High School, in Silverdale, Washington.

SUMMARY OF PUBLIC COMMENTS

A total of 24 comments were received by the Navy concerning the Proposed Plan. Twelve written comments submitted in a letter during the comment period were also discussed at the Public Meeting. Eleven questions and comments were provided verbally by four people at the public meeting. One additional comment letter was submitted to the Navy during the comment period outside of the public meeting. In general, comments received were supportive of the preferred alternative. Many of the written submittals raised concerns or questions on more than one issue. Some of the comments pertain to similar issues and questions about the Proposed Plan and the contamination at Site F. Comments regarding similar concerns and questions were grouped accordingly and addressed in this responsiveness summary by topic areas.

Copies of the transcripts for the meeting are available at all the public repositories listed in the Community Relations section of the Record of Decision and a copy is part of the Administrative Record. Copies of the letters received have been included in the Administrative Record.

RESPONSE TO COMMENTS

The comments were grouped into nine topics which address the issues raised at the public meeting and during the public comment period. Each of these topics is discussed separately below.

1. Shallow Aquifer Characterization and Potential Impacts to Seeps and Off-Base Water Supplies

The following concerns were raised in the public comments:

(a) Potential interconnection of the Shallow Aquifer on base with off-base, shallow zones of groundwater which are used for domestic water supply at some locations;

(b) Potential future impacts to the seeps and downstream surface water, which is used by off-base residents of Old Bangor for various (non-drinking water) uses. One or more questions were also raised regarding what monitoring of the seeps had been and will be conducted, and the time estimated for ordnance compounds to reach the seeps; and

(c) What is the cause of long-term water level decline in the Shallow Aquifer?

Response:

Each of these comments is addressed individually below.

(a) The Navy concurs that there is uncertainty regarding the possibility that the Shallow Aquifer is connected with shallow groundwater zones off base which are locally used for water supply. However, whether the Shallow Aquifer at Site F is interconnected with shallow groundwater off base or not does not change the Navy's commitment to addressing contamination in the Shallow Aquifer at Site F, nor does it change its selected alternative for doing so. The objective of the selected alternative is to restore the Shallow Aquifer to drinking water standards. The enhanced groundwater treatment system will be operated and modified as appropriate to achieve the established cleanup levels, to the extent practicable, and provide long-term protection of human health and the environment.

The variety of available geologic and hydrologic information provided in the RI/FS supports the hypothesis that the Shallow Aquifer present at Site F (thick sequence of advance outwash sand) does not extend off base in the direction that groundwater from Site F is moving (in the vicinity of Old Bangor). The Navy agrees that it is possible that groundwater discharge from the Shallow Aquifer via seeps may provide recharge to shallow groundwater zones west of the base boundary which, based on review of well logs from the area, appear to be within sand zones within glacial till.

(b) As discussed in the response to (a) above, the objective of the selected alternative is to restore the Shallow Aquifer to drinking water standards. This objective includes preventing further migration of the groundwater contamination into uncontaminated portions of the aquifer, which is the sole objective of the Site F interim remedial action (IRA). By preventing migration of the groundwater contamination, the seeps will be protected. The Navy is confident that the groundwater remediation will be effective in protecting the seeps in the long-term, and thus protect users of surface water originating at the seeps.

As discussed in the public meeting, locations where the seep discharge is diverted across the base boundary into Old Bangor were sampled as part of the RI/FS in 1991. Subsequent sampling at monitoring wells closer to the zone of groundwater contamination confirm that the groundwater contamination is currently at least a mile from the seeps. Groundwater sampling of on-base compliance monitoring wells, positioned outside the zone of contamination, will be an integral part of the groundwater remediation program to track the zone of contamination.

The RI/FS presents a time range of 10 to 30 years for the most mobile groundwater constituents from Site F to reach the seeps. Ten years represents a reasonable maximum exposure (RME) estimate which was derived for the purposes of the risk assessment using highly conservative values for each physical and chemical transport parameter (e.g., maximizing flow velocities and minimizing contaminant retardation). Thirty years represents an average value which, based on physical and geochemical site conditions, is considered a more probable outcome. Consequently, 30 years was presented in the Proposed Plan.

(c) The reason for the water level declines measured between the mid-1970s and early 1990s is uncertain, and is likely a combination of effects including long-term regional drought. However, the Navy is confident that the decline is not due to improperly decommissioned old monitoring wells extending to the Sea Level Aquifer, or overpumping of the Shallow Aquifer at SUBASE. It should also be noted that water levels in the Shallow Aquifer were generally stable (disregarding seasonal fluctuations) over the two-year period of RI/FS monitoring (1990 to 1992).

A thorough review of the information on the old (before 1976) monitoring wells installed at Site F indicates that all these wells were installed in the Shallow Aquifer; none of them extended to the Sea Level Aquifer. A technical memorandum is available in the Administrative Record which documents information on these old (pre-1976) wells, and their completion in the Shallow Aquifer. There are existing deep monitoring wells in the general vicinity of Site F which were installed in the late-1970s by the Navy to monitor recharge of groundwater associated with dewatering during construction of the Delta Pier. Well construction data for these wells indicate the use of grout seals during installation. The grout seals prevent movement of water within the borehole, therefore these wells also should not provide a conduit for flow between aquifers.

There are no water supply wells in the Shallow Aquifer at SUBASE, Bangor. Although there are domestic wells in the Shallow Aquifer off base to the east of Site F, the combined yield of these wells is insufficient to effect a uniform 11-foot water level drop in the transmissive regional aquifer.

Because the water level drop was uniform in monitoring wells located almost 3,000 feet apart, cessation of discharge at the wastewater lagoon at Site F also doesn't account for this magnitude drop in water level since, during active discharge, 11 feet of groundwater mounding would not have extended uniformly 3,000 feet from the lagoon.

Data collected from Sea Level Aquifer well TH-11S during the RI/FS indicate groundwater levels in the Sea Level Aquifer in the Site F vicinity have also dropped 8 to 12 feet between 1977 (well installation) and 1991. Possible long-term regional drought may account for the observed decline in both the Shallow and Sea Level Aquifer water levels.

2. Potential Impacts to Sea Level Aquifer

Summary of Questions:

One question from the public related to monitoring of the Sea Level Aquifer.

Response:

The Sea Level Aquifer is the first aquifer beneath the Shallow Aquifer. A downward hydraulic gradient exists between the two aquifers, therefore groundwater flows from the Shallow Aquifer toward the Sea Level Aquifer. The two aquifers are separated by a 60- to 80-foot thick, low-permeability aquitard (roughly 100,000 times less permeable than the aquifers), which greatly restricts the rate of groundwater flow between aquifers. Furthermore, the fine-grained clayey silt and higher percentages of organic matter comprising the aquitard will cause substantial adsorption of organic chemicals (like ordnance). Because of the very low rate of groundwater flow through the aquitard and the substantial adsorption of contaminants expected to occur within the aquitard, negligible ordnance concentrations would be expected to reach the Sea Level Aquifer.

The SWFPAC (Strategic Weapons Facility Pacific) well, screened solely in the Sea Level Aquifer, was sampled as part of the RI/FS sampling program. This well is located about a mile northwest of the former wastewater lagoon at Site F. It is important to note that the groundwater contamination from Site F doesn't reach the bottom of the Shallow Aquifer until it has migrated more than 1,000 feet from the former lagoon. Although a compliance monitoring plan for the groundwater remediation program has yet to be developed, it will include periodic monitoring of the SWFPAC well for ordnance to provide early warning of any constituent migration into the Sea Level Aquifer.

3. Site F Interim Remedial Action Compliance Monitoring

Summary of Questions:

Questions were raised by the public regarding compliance monitoring criteria for the Site F interim remedial action (IRA), and the time for hydraulic containment of the groundwater contamination to be achieved once the IRA extraction and reintroduction wells were operational.

Response:

Compliance with the cleanup objectives will be evaluated by measuring groundwater constituent concentrations in the Shallow Aquifer as the remediation progresses. The cleanup levels (as listed in the Proposed Plan and in this Record of Decision) are the criteria that will used to evaluate compliance with the cleanup objectives.

Hydraulic containment will be determined using both groundwater quality data from wells located downgradient of the current extent of groundwater contamination, and from water level data collected in the vicinity of the extraction wells. Once operational, the groundwater extraction and reintroduction system should achieve containment relatively quickly (perhaps within several weeks of operation depending on required adjustments). Adjustments of the extraction/reintroduction system (e.g., adjusting individual extraction well pumping rates) may be necessary in the first few weeks of operation of the extraction and reintroduction systems.

4. Groundwater Remediation Plan for the Selected Alternative

Summary of Questions:

Questions were received from the public regarding:

(a) How the RI/FS groundwater alternatives correspond to the preferred alternative for groundwater remediation;

(b) Performance and cost of UV/Ozone for groundwater treatment; and

(c) The locations of the reintroduction wells.

Response:

(a) The selected alternative for groundwater remediation corresponds to groundwater Alternatives 7 or 8 in the Site F Feasibility Study. The only difference between groundwater Alternatives 7 and 8 in the FS was the duration of operation (10 and 30 years, respectively). The duration of operation of the selected alternative groundwater system will be based on performance and compliance with cleanup standards rather than a specific time frame. Consequently, the duration of operation was not specified in the Proposed Plan, and is not specified in this ROD. System design and optimization will largely define the expected period of operation; however, it is uncertain how well the actual extraction system performance will compare with the groundwater modeling results.

(b) Analytical results obtained during the field test (Phase III) portion of the UV/Oxidation Treatability Study indicate that UV/Ozone treatment can effectively achieve cleanup levels for ordnance compounds detected in Site F groundwater, including DNT.

The estimated costs of UV/Ozone treatment provided on Figure 6 of the Proposed Plan include $40,000 per year for operation and labor cost for system maintenance. The basis of this cost estimate (influenced largely by expected influent ordnance concentrations in the extracted groundwater) are significantly different than the assumptions used to develop the cost estimate presented in the June 18, 1993, TRC meeting. The fact that the two estimates yielded nearly identical overall costs is purely coincidental.

(c) As stated in the public meeting, the reintroduction wells for the Site F IRA are located adjacent to SWFPAC support, which is downgradient of the leading edge of the groundwater contamination in the Shallow Aquifer. The locations of potential additional reintroduction wells for the enhanced groundwater treatment alternative will be decided during the design phase.

5. Soil Remediation Plan for the Selected Alternative

Summary of Questions:

Some questions raised during the public meeting addressed the biological treatment process, specifically, time frame, ingredients, and treatment byproducts; potential dust generation; and what will be done with the treated soil. In addition, a comment addressed the infiltration barrier and potential additional soil treatment in the future.

Response:

As discussed in the public meeting, on-site biological treatment of Site F soils should be completed within one year of the time of its implementation. However, this does not include the time period associated with design, construction, and system startup. Amendment added to contaminated soil during the biological treatment process will include organic materials (e.g., potato waste, manure, sawdust) which provide nutrients to the microorganisms. Results from treatability studies have demonstrated that the ordnance compounds are broken down into less complex, less toxic compounds. The studies indicate the treated soils meet direct contact soil cleanup levels for all ordnance compounds and their degradation products. During treatment, dust generation will be controlled by adding water, which is used as a normal part of the treatment process. Once treatment is complete, the treated soils will likely be used to regrade the excavation and overflow ditch at Site F prior to installation of the infiltration barrier.

The infiltration barrier will greatly limit migration of constituents from soils into the Shallow Aquifer. The infiltration barrier will be specifically designed to reduce infiltration of precipitation and thereby prevent further leaching of residual ordnance constituents to the Shallow Aquifer.

6. Laboratory Analysis of Ordnance Compounds - Practical Quantitation Limits

Summary of Questions:

One public comment addressed the adequacy of current analytical methods in quantitating ordnance concentrations down to the cleanup levels.

Response:

The Navy recognizes past limitations in quantitating ordnance compounds, particularly RDX, in soil and groundwater. However, current analytical methods provide practical quantitation limits (PQLs) below cleanup levels, with the exception of DNT and RDX soil cleanup levels for protection of groundwater, as stated in the Proposed Plan. However, because the groundwater protection soil cleanup levels were estimated using conservative assumptions, and the volume of soils at Site F with concentrations between the estimated cleanup level and the PQL is likely to be small, soils with RDX or DNT concentrations at or below PQLs (1 mg/kg RDX and 0.5 mg/kg DNT) should not pose a risk to groundwater. Furthermore, the infiltration barrier will extend beyond the zone of contaminated soils, thus providing a measure of safety for the soils potentially containing ordnance concentrations below PQLs but above estimated groundwater protection cleanup levels.

7. **Potential Impact of Site Contamination on Proposed RV Center and Golf Course**

   Summary of Questions:

   One question raised during the public meeting concerned the proximity of soil contamination at Site F to a proposed RV Center and golf course driving range at SUBASE, Bangor.

   Response:

   As discussed in the public meeting on the Site F proposed plan, the proposed RV Center and driving range are approximately 3,300 feet from Site F, and are well outside the zone of soil contamination at Site F.

8. **Process for Removing a Site from the National Priorities List**

   Summary of Questions:

   One question raised during the public meeting regarded the process for removing Site F from the National Priorities List.

   Response:

   According to the National Contingency Plan (40 CFR 300.425(e)), EPA, in consultation with the State of Washington, could delete SUBASE, Bangor from the National Priorities List (NPL) after determining that the Navy has implemented all appropriate actions. Individual operable units (e.g., Site F is operable unit 2) are not eligible for delisting; only the NPL Site (SUBASE, Bangor) in its entirety could be delisted. The State of Washington must concur with the delisting. As part of the delisting process, the public would be made aware of EPA's intent to delist SUBASE, Bangor by publishing notices in local newspapers and posting a notice in the Federal Register.

9. Rationale for Choosing the Selected Alternative

Summary of Questions:

Two general comments were received regarding the overall decision to take action at Site F. One comment received during the public meeting expressed approval for the selected alternative. One comment letter received during the comment period stated that, rather than undertaking active remediation at Site F, monitoring of off-site wells should continue with the Navy supplying water to these residents in the future if their wells ever become contaminated.

Response:

The Navy is committed to implementing permanent solutions to the extent possible, which provide long-term protection of human health and the environment. The No Action alternative could in the future, based on the results of the RI/FS, result in risk to humans or aquatic life encountering contaminated soil or groundwater (seeps) at Site F. It is the intent of the Navy in this proposed action to be proactive in addressing this contamination to avoid future potential impact. Furthermore, the Navy is required, under the terms of a Federal Facility Agreement, to comply with applicable environmental regulations. Because the existing contamination represents a potential risk (as determined using EPA's standard risk assessment), environmental regulations require cleanup be undertaken unless it can be demonstrated it is inordinately costly to do so.

The Navy feels the selected remedy provides a cost-effective program for reducing site risk. In general, the public who have commented on the proposed cleanup have been supportive.
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